ENGINEERING CASE LIBRARY

ECL 269

ROARING SPRING FOUNDRY

This case describes the effort of Roaring Spring Foundry to achieve compliance with Occupational Safety and Health Administration (OSHA) standards for free silica and noise following citations for violation in 1973 and 1979. Roaring Spring is a small gray iron foundry in eastern Pennsylvania manufacturing decorative Victorian lamp posts, junction boxes, and other electrical equipment for exterior lighting. Included in the case are: (1) toxicology of silica and olivine; (2) economic analysis of using olivine and/or engineering controls; (3) measurement of airborn free silica; (4) engineering controls; (5) other insights into the response to the OSHA Foundry Emphasis Program of foundry cleanup in the 1970s.

Robert Jennings Heinsohn, Ph.D., P.E.
The Pennsylvania State University

This engineering case was prepared in fulfillment of P. O. 85-35131 under the sponsorship of the Division of Training and Manpower Development, National Institute for Occupational Safety and Health.

Names (but not facts) have been changed.

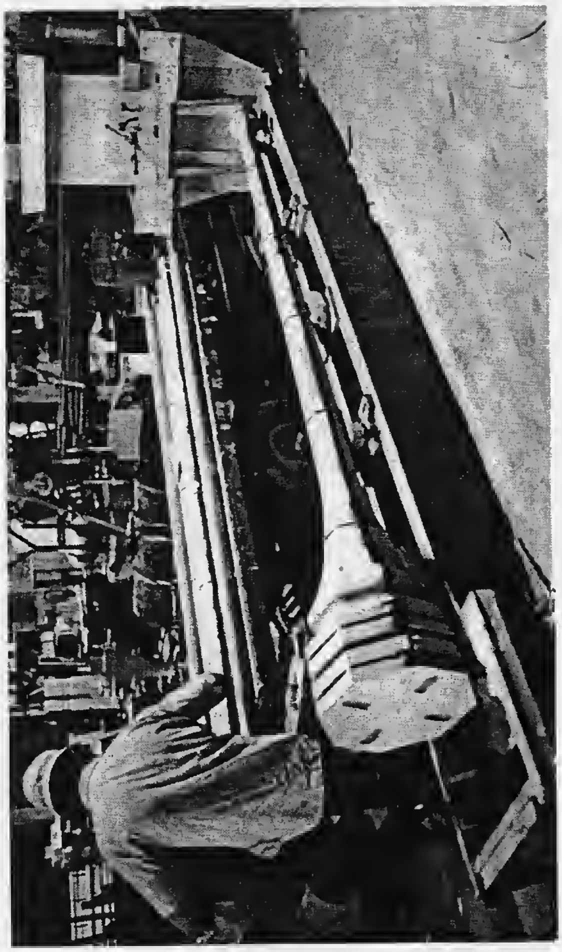
PART I - NARRATIVE

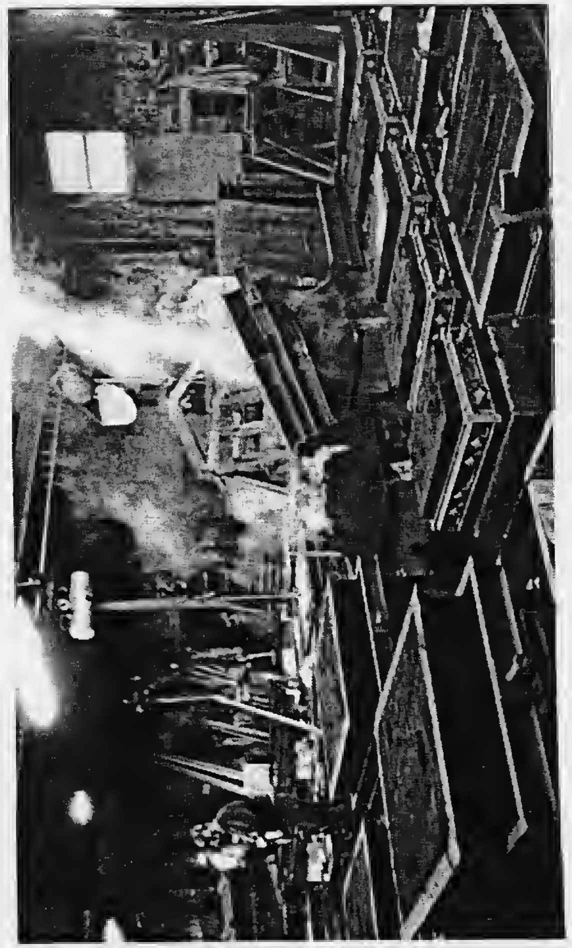
Roaring Spring Foundry is a small gray iron foundry in eastern Pennsylvania. Roaring Spring, like Valley Forge several miles away, is a colonial community whose industry was derived from the river. The company has been at this location since 1856, when it manufactured stove products. Over the years, buildings have been added in a piecemeal fashion. The company president is Mr. Stanley Martin. Mr. Martin's father was formerly the president and Stan grew up assisting his father in the business. Between 1973 and 1979, the company employed about 50 people and had yearly sales of approximately 4 million.

The foundry buys scrap metal, primarily shredded automobiles. The scrap is melted in two gas-fired reverberatory furnaces. Specific alloy metals are added, depending on the type of casting. Molten metal is poured into ladles suspended from a monorail and moved by hand to the molds. Approximately 10 tons of metal is poured each day; of this, 75% is gray iron and the balance is ductile iron. Only a small amount of aluminum is cast. The majority of the castings are decorative Victorian lamp posts and large electrical junction boxes for outside lighting systems. Figures 1 and 2 shows the castings made in the foundry. A variety of small castings are occasionally poured. Small castings are made on hand-operated squeeze machines and contain oil-shells, or air-set cores. Lamp posts and other large castings are molded by hand in special flasks on the foundry floor. These large castings often contain air-set cores. Air-set molds are also made for large, thin-walled casings where the wall thickness is important.

Between 1973 and 1979 the foundry was divided into 10 work stations shown in Figure 3. Table 1 summarizes the number of individuals at each station. Station 1 is the portable grinding room. Surface imperfections on all large castings were removed by four or five people using pneumatic hand-held grinders or large grinding wheels suspended from the ceiling on movable tracks. The suspended grinding wheels had local ventilation hoods (an inlet opening close to the point of grinding) to collect particles. Some of the hand-held grinders had silencers for the discharged air and others did not. In all cases, the discharged air was seen to resuspend dust lying on the floor or other horizontal surfaces. There was also a large exhaust fan located on the wall next to the door. By 1977 all men working in station 1 wore positive pressure, airflow helmets with flip-up visers. Figure 2 shows workers in work stations 4 and 5 and Figure 4 shows the apparel and hand-held pneumatic grinders used by workers in station 1. Once the surface imperfections were removed, the large castings were moved to the machining room where critical surfaces were produced, holes drilled and important dimensions achieved.

Figure 1. Castings made by the Roaring Spring Foundry.





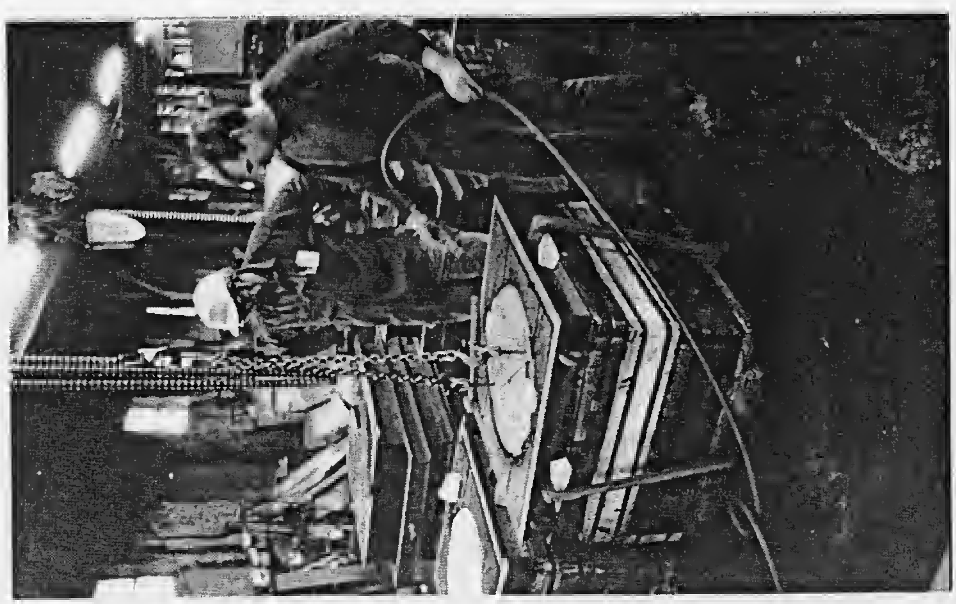


Figure 2. Casting operations.

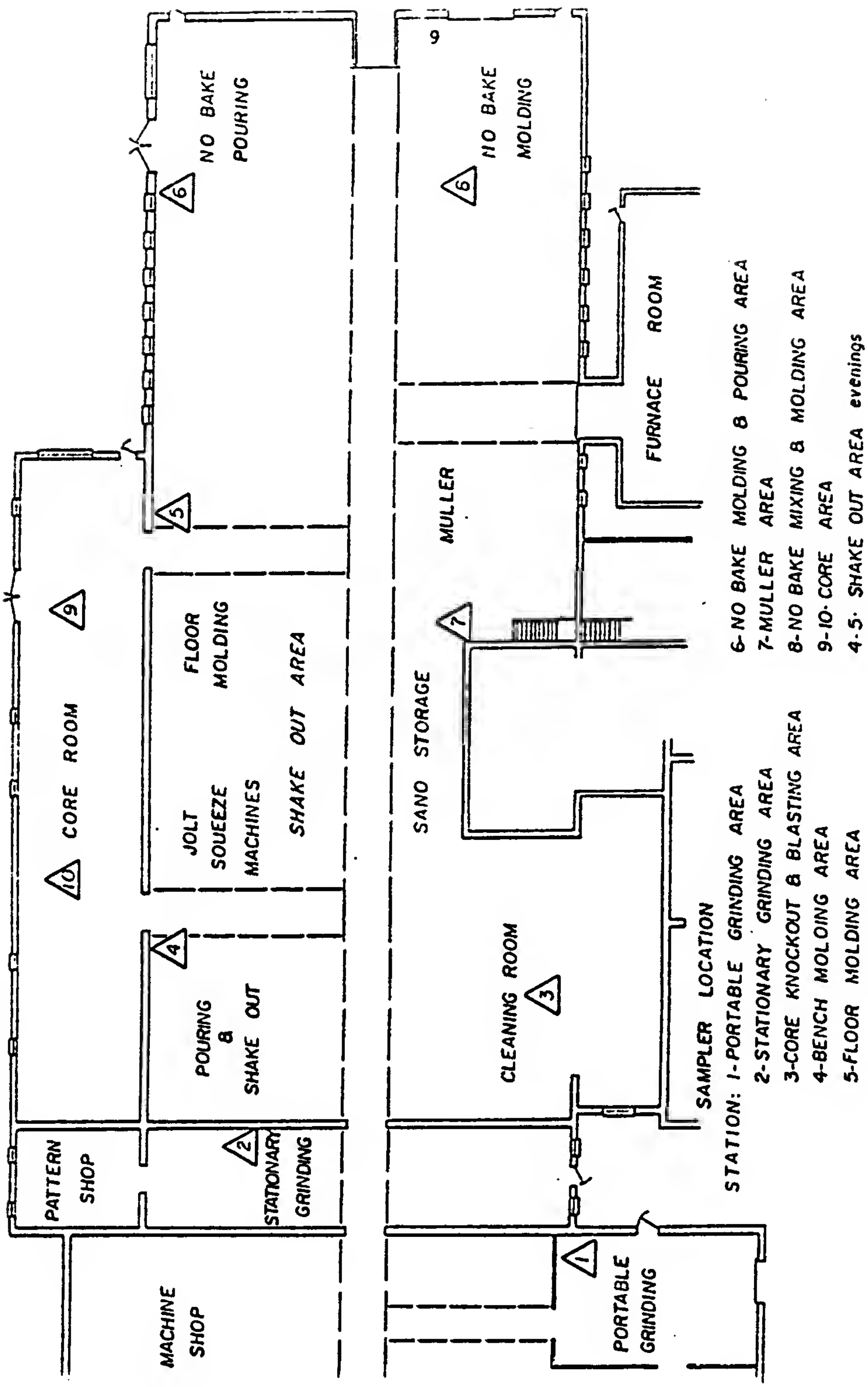


Figure 3. Work stations in the foundry.

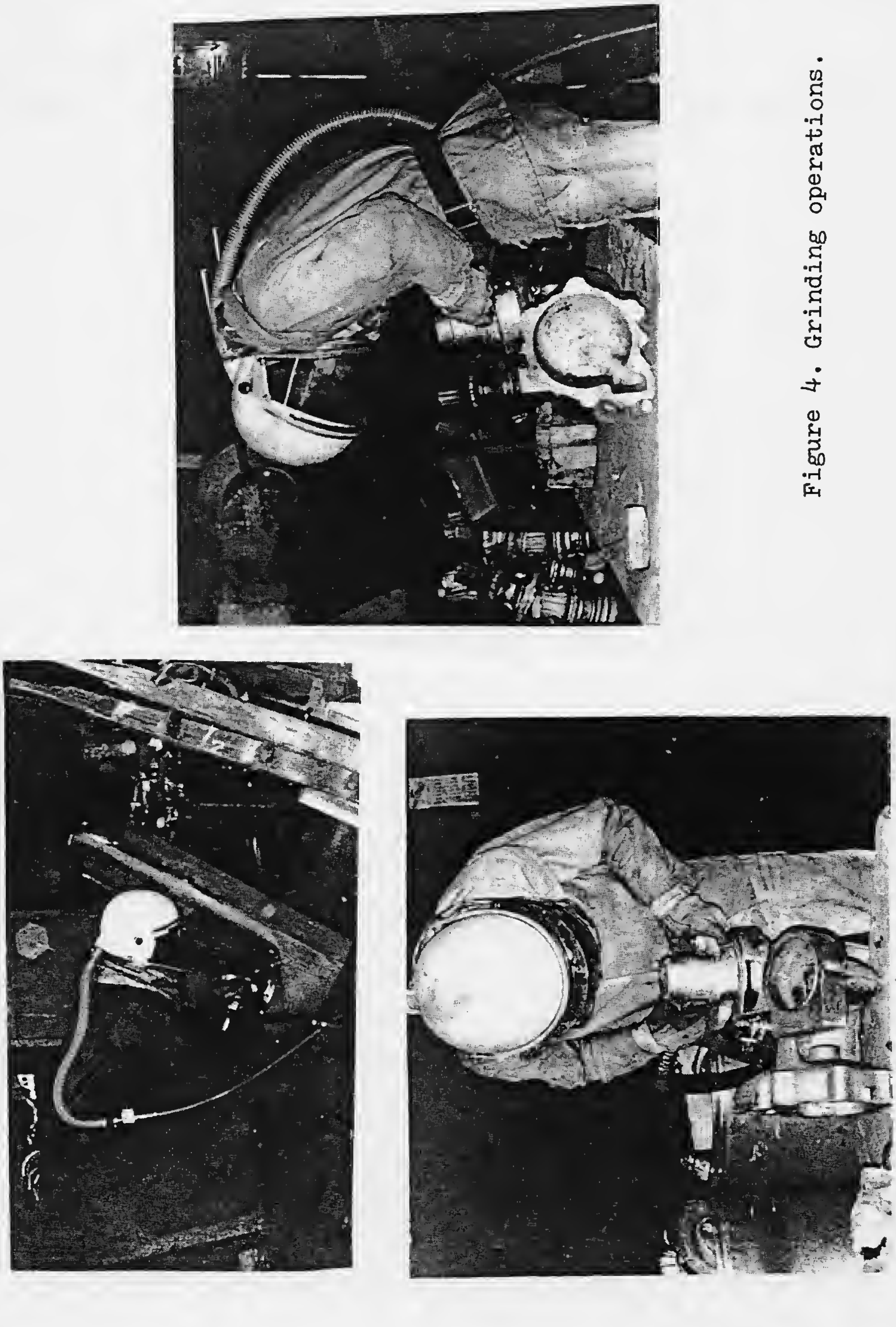


Figure 4. Grinding operations.

TABLE 1
MANPOWER AT EACH WORK STATION

Station No.	Activity	No. of Persons
1	Portable grinding	4-5
2	Stationary grinding	1
3	Core knockout and blasting	3
4	Bench molding	3
5	Floor molding	5-6
6	No-bake molding and pouring	4-5
8	No-bake mixing and molding	
7	Muller	1
9-10	Core room	1
4-5	Shake out	3-4 (evenings only)

Station 2 is the stationary grinding room containing three pedestal grinders and a cut-off machine suspended from the ceiling. Two pedestal grinders and the cut-off machine had local ventilation hoods (as described above). One man worked regularly in Station 2 and was dressed as in Figure 4.

The main floor of the foundry had five work stations designated 3 to 10. Station 3 included the core knock-out area, the sand blasting area, and the shot blast area. Several people worked in these areas, but only one of them was there at all times. Molding was done at Stations 4 and 5. There were three bench molders along the center aisle, and five to six men (molders and helpers) in the floor molding area. The muller was located at Station 7 and was adjacent to the green sand storage bin. One man operated the muller and drove the frontloader to deliver sand to the molding area. Stations 6 and 8 were in the no-bake area. Molding and pouring was done at Station 6. Sand was mixed and molds were made at Station 8. The core room was adjacent to the molding areas. One man worked in the core room on the day shift at a table between Stations 9 and 10. The small sand cores were made in this area.

Shake-out took place each afternoon and evening. The green sand molds were shaken out where they were molded. The small molds were done by hand, and the larger ones were done with a forklift truck. The pieces were collected by either a frontloader or a forklift and delivered to the cleaning room (Station 3). After all the pieces were collected, the sand was returned to the green sand storage bin. The

no-bake molds were carried to an open area at the entrance of the furnace where they were knocked apart with a forklift.

The building containing Stations 2 through 10 was a one-story frame building with a low-pitch roof. The entire space under the roof was open. The outside walls of the building were approximately 20 feet high, and the height to the peak of the roof was approximately 35 feet. The portable grinding room and machine shop were in an abutting but separate building. The ceiling in the portable grinding room was approximately 15 feet high. The furnaces were in a separate building below the floor level of the foundry with access to the foundry through a short corridor. There were no doors separating the various work stations.

In 1970, there were 390 foundries in the State of Pennsylvania employing approximately 41,255 workers and having a payroll of $350 million. The majority of these firms were small and used local supplies of scrap metal to provide castings for local manufacturing industries. In 1973, the Pennsylvania State Legislature passed legislation removing a provision that limited the maximum amount that could be paid to silicosis victims. This action caused a private insurance company that insured 70% of the state's foundries to discontinue silicosis coverage. Foundries found it very difficult to find insurance with other carriers. Simultaneously, OSHA began a National Emphasis Program and targeted the foundry industry for cleanup. The objectives of the program were later changed and the program was renamed the Foundry Emphasis Program. Foundries in Pennsylvania were visited by OSHA. Many violations were found, and citations of varying severity were issued. As a consequence, many foundries went out of business or moved to neighboring states where they could at least find insurance. Exhibit 1 is testimony given by the Pennsylvania Foundrymen's Association before the House Labor Relations Committee in 1975 summarizing the plight of the state's foundries. On October 2, 1973, Roaring Spring Foundry was cited by OSHA for free silica violations for the muller operator and the stationary and portable grinding operators.

The citation required Mr. Martin to initiate changes in the foundry to comply with OSHA standards. Mr. Martin decided to pursue four methods to bring the plant into compliance:

(1) Replace all or a portion of the silica sand by a nonsilica molding sand;

(2) Install engineering controls to capture silica particles before they became airborne;

(3) Outfit workers in personal protective devices to protect them from inhaling free silica particles; and

(4) Install engineering controls to reduce the noise level.

* * * (RETYPED FROM ORIGINAL) * * *

(Letterhead):
PENNSYLVANIA FOUNDRYMEN'S ASSOCIATION
Post Office Box 70 Labrobe PA, 15650

TESTIMONY BEFORE HOUSE
LABOR RELATIONS COMMITTEE

September 5, 1975

Chairman Valicenti, Members of the House Labor Relations Committee and Staff:

My name is Bruce Eckert. With me today is the President of the Pennsylvania Foundrymen's Association, Donald Y. Clem. On behalf of Mr. Clem and the Association, I want to thank this Committee for affording us the opportunity to address you on what are very timely subjects for our industry in Pennsylvania.

A. BACKGROUND

As a bit of background to acquaint you with our Association and the foundry industry itself, the Pennsylvania Foundrymen's Association was organized last year to represent the interests of approximately 300 foundries which are currently operating in Pennsylvania.

The foundry industry is one of the nation's most basic industries and indeed, its sixth largest industry.

Pennsylvania has always been a leader in this industry and it has one of the largest concentrations of foundries of any state in the Union. Based on a recent survey which was conducted by our Association of its member foundries, I can tell you that the foundry industry accounts for approximately 40,000 jobs in Pennsylvania, pays in wages along approximately $350,000,000 into Pennsylvania's economy, contributes approximately $7,000,000 into Workmen's Compensation benefits, $6,000,000 into Unemployment Compensation and $56,000,000 in other federal, state and local taxes.

These are, I think you will agree, impressive figures. I also hope that you will be, by the end of our Testimony, equally impressed by our assessment that the foundry industry in Pennsylvania is in serious trouble.

Between 1968 - 1974, 360 foundries nationwide closed their doors, about 50 of which were here in Pennsylvania. That's equal to a loss of 5,500 jobs and $50,000,000 in wages. And the trend is not at the present reversing.

EXHIBIT 1

Why the closings? Serious raw materials shortages and highly escalating raw materials prices; soaring labor demands in a high labor intensified industry; rapidly escalating energy costs and finally, the reason for our Testimony today, lack of adequate capital availability and the unaffordable costs for compliance requirements of programs such as OSHA.

With the brief background analysis, I would like to call on Mr. Clem to specifically address the foundry industry and OSHA.

B. OSHA

I think I speak for the industry as a whole when I say that we do not disagree with the goals set forth in the legislation on environmental quality and occupational safety and health.

We do, however, disagree with the implementation of those goals under the regulations of OSHA. Excessive regulations have greatly affected all foundries and to a large extent, have been the principal cause of the closing of many of the smaller, jobbing foundries.

The foundries which have not closed have been forced to expend capital to meet conflicting and, in my cases, immeasurable standards with unproven control equipment. The net result has been a major reduction in working capital, vast increases in non-productive operating costs and a prohibitive escalation of energy consumption.

In the past 5 - 10 years, Pennsylvania foundries have expended approximately $130,000,000 for environmental control equipment, mostly external air pollution control equipment required by EPA regulations. And, the secondary cost and effect of those regulations is often as great as the regulations themselves. For example, prior to the promulgation of air pollution control regulations, the foundry industry as a whole had no waste water problems. Air cleaning systems brought about voluminous water usage which in turn required or will require installation of water treatment systems of a cost equal to the original air cleaning system. The water treatment systems in turn, will bring about further solid waste disposal systems.

On top of all these expenditures comes OSHA regulations for internal air pollution control, new dust, noise and heat stress standards. The potential outlay for foundries in these areas could far exceed expenditures for external air and water pollution control.

Let me get specific!

One of our member foundries--and I might add, one of our more up-to-date, progressive foundries, was cited by OSHA in 1974 for exposing its employees in various operations to excessive levels of respirable nuissance dust. They were ordered to provide immediately for short-term abatement, submit a detailed plan for long-term abatement by a certain date and completely abate the excessive dust levels by January 16, 1976.

A feasibility study of these internal environmental problems was undertaken by that foundry with the following projected costs:

Installation of four ventilation systems - dust collection	$	704,800
New sand system		243,500
Ventilation and shell core machine		26,200
Purchase of electrical transformers to implement ventilation system		137,700
TOTAL	$	1,262,200

This same foundry was also cited for exposing its employees in various operations to excessive levels of noise, i.e. above 90 decibels. Even if our workmen were put into cubicles to work with the best sound equipment available, this decibel level could not be obtained; and to do that would cost approximately $500,000.

Let's add this $500,000 for noise abatement to the $1,262,000 for dust abatement and throw in an added $100,000-$150,000 for increased energy costs to run these systems and you arrive at a total of close to $2,000,000. And all of this in 2 years.

Let me add another interesting statistic. I refer to you an article in Industrial Magazine, Vol. 41, No. 6, June 1972, which addressed "Silicosis and Diseases of Retired Iron Foundry Workers." This was a study of 1,058 retirees, only 76 of whom showed signs of pulmonary silicosis and only 9 of that group were truly disabled by silicosis, thereby representing 0.9% of the entire group and 1.2% of the silicotics. Six other studies which had been conducted in states such as Massachusetts, Connecticut, Wisconsin and New York were documented in that article and the incidence of silicosis ranged from 2.5% to 8.8% per studied group.

So, in order to abate a condition that has a disabling effect on less than 10% of its work force, the above-mentioned foundry has to expend approximately $2,000,000 (inclusive of noise abatement for which studies for reduced hearing capacity are few and far between).

That foundry has a total depreciated value of approximately $3,000,000.

As good businessmen and women, how many of you would invest 70% of your total plant value into non-productive, non-income producing equipment had to work for you about 25 years to even have contracted the condition which you seek to abate)? Not many, I'm sure. And for those of you who would, how many of you could convince your banker why he should lend money for such a "prudent" venture?

That's the problem! Unlike normal capital investment, dollars spent in non-productive pollution control projects do nothing to strengthen a foundry's long-term profitability--and thus improve its credit worthiness. The result is rather to reduce the foundry's overall return on investment, and to reduce the productivity while

increasing operating costs; thus doubly impairing the firm's present and future ability to finance new productive capacity.

That's why foundries have closed and will continue to close.

What are the solutions?

I call to your attention a U.S. Department of Commerce study of the foundry industry undertaken by Robert E. Curran, dated March 24, 1975, as part of "Project Independence" in which he sets forth various recommendations such as:

1) Investigation by the government of the impact of pending environmental standards;

2) Availability of small business loans for air pollution control purchases;

3) Establishment of an independent appeal mechanism under OSHA for foundries which gives consideration to national defense needs, local conditions and financial factors;

4) Revision of IRS regulations to enable investments in "non-productive" equipment to be expensed or written off at a more rapid rate;

5) Expenditure of increased research and development funds into environmental and energy related problems of foundries.

To these I would add the suggestion that:

6) OSHA be made to accept individual protective devices as a permanent control method. Last year, Pennsylvania foundries spent $150,000,000 on employee safety equipment, yet that expenditure is of no moment in meeting OSHA standards.

Should Pennsylvania foundries undertake the expenditures required by OSHA, their competitive position vis-a-vis foundries in other states will not be affected thereby, since OSHA is a federally-enacted program.

There is, however, a situation occurring here in Pennsylvania which could very quickly make Pennsylvania foundries non-competitive and lead to a further closing of foundry doors. Bruce Eckert will speak briefly to that issue.

C. WORKMEN'S COMPENSATION - SILICOSIS BENEFITS

Within the last few months, Pennsylvania foundries have been confronted with a crisis in Workmen's Compensation Insurance; namely, their being declared "uninsurable" in this area by Pennsylvania Manufacturer's Insurance Company, a company which insures approximately 70% of the foundries in this state.

Their reason for reaching this conclusion? The dramatically increased claims and benefits for silicosis which have arisen since the 1973 legislative amendments placed occupational diseases under the provisions of the Workmen's Compensation Act.

Prior to July 1973, the old Occupational Disease Act governed claims for silicosis, the occupational disease of greatest interest to foundries and their insurers. Under that Act, there was a statutory maximum benefit for a total disability occasioned by silicosis of $12,750. When the maximum was reached, this totally disabled worker became entitled to $100 a month for life. Survivors' benefits were limited to the $12,750 statutory maximum. If the worker's exposure had been in excess of five years in the employment of one employer, the employer was liable for 60% of the benefits and the Commonwealth 40%. If there were multiple employers, the Commonwealth was 100% liable. A typical claim submitted under that Act amounted to $12,000-$15,000.

Since July 1973, occupational disease benefits are, of course, linked to the statewide average weekly wage which, at present, is $171. There is no statutory maximum benefit; survivors' benefits are not limited except by death or re-marriage of the widow or a child reaching the age of 18. Full medical and hospital benefits are provided and the Commonwealth no longer pays any share of these benefits.

Actuarially, silicosis is not a killer disease. In other words, it does not reduce a working man's lifespan by any appreciable number of years.

Therefore, today's projected incurred costs for a silicosis claim submitted by the following persons are as follows:

a) For a 68-year-old male -
9.618 (life expentancy) x 8892 ($171 x 53) = $85,523.25

b) For a 62-year-old male -
11.770 x 8892 = $104,658.84

c) For a 60-year-old male -
12.468 x 8892 = $111,025.51

d) For a 50-year-old male -
15.963 x 8892 = $141,943.00

Add to this financial situation the following dates:

1) There is a statutory presumption that an employee's "occupational disease" arose out of and in the course of his employment;

2) There has been a dramatic increase in silicosis claims within the last 18 months, <u>the majority of which have been filed within months of the claimant's retirement at age 65</u>;

3) Historically, the Referee System in Pennsylvania has been extremely liberal in assessing occupational disease claims;

4) Compensation is awarded for occupational disease claims not on the basis of partial disability but on an all or nothing basis--mostly all or full, 100% disability.

In short, adding the financial benefits to the above-mentioned facts, one arrives at the conclusion which has been reached by foundry workers, foundry management and foundry insurers--silicosis benefits in Pennsylvania today are a form of pension benefits, not wage replacement or loss of earnings benefits.

And neither the insurers nor the State Workmen's Insurance Fund, where foundries have had to turn in ever-increasing numbers, are prepared to finance this type of pension benefit. It will, without doubt, bankrupt each of these insurers, if allowed to continue.

The only preventatives are Pennsylvania foundries closing their doors and leaving this state--as many foundries are presently considering, and as has happened in Pennsylvania's asbestos industry--or realistic legislative relief to bring benefits in line with actual disability and earnings loss.

It is an historical fact that a similar situation with regard to black lung disease has, over the last few years, occurred in the coal mining industry in Pennsylvania.

As of this date, the cost per $100 of salary for Workmen's Compensation Insurance is $40/100. At present, Pennsylvania foundries pay approximately $5 - $6 per $100 of salary for Workmen's Compensation coverage--a rate which is comparable to surrounding states.

The average foundry in Pennsylvania has an annual payroll of $1,000,000. An increase of Workmen's Compensation rates from 5 - $40/100 of salary would cost an additional $350,000 per year.

That increase would unquestionably remove the profit margin for each and every foundry in this state or make Pennsylvania foundries

The end result--Pennsylvania's loss of yeat another vital industry.

Quite frankly, our Association will seek legislation action in this area. As of this time, we have no finalized legislative proposals; however, we offer some general suggestions for your consideration:

1) A study of the statewide incidence of silicosis within the foundry and related industries over the last ten years;

2) Removal of silicosis claims from the provisions of the Workmen's Compensation Act;

3) A pooling arrangement of insurers for the purpose of affording Workmen's Compensation Insurance for occupational disease;

4) Provision for the award of partial occupational disease benefits for partial disability;

5) Provision for post-retirement occupational disease benefits at a rate other than the statewide average weekly wage;

6) A study of Pennsylvania's Referee System; its procedures for determining liability, assessing injury and awarding damages.

Mr. Martin had been active in professional organizations related to the foundry industry for many years. He participated actively in affairs of the American Foundrymen's Society (AFS) and its state affiliate, the Pennsylvania Foundrymen's Association (PFA). Through the PFA he became involved with the Foundry Option in the Department of Industrial Engineering at The Pennsylvania State University (Penn State) and served on its Industrial and Professional Advisory Committee, which met regularly to provide guidance to the Department on its programs of instruction and research. Through long association with these organizations, Mr. Martin knew individuals whom he could contact for assistance. As an aggressive businessman, he was not hesitant to ask for assistance.

In October, 1973 he contacted DuPont to explore the use of a molding sand called Biasill. In 1973, he contacted the Small Industries Research Program (SIR) at Penn State and the AFS and PFA for assistance in running a test that substituted Biasill for silica sand. The SIR program provides technical and financial assistance in the form of matching funds to small industries. In March 1976, Mr. Martin contacted the International Mineral Company (IMC) concerning another nonsilica molding sand called olivine, which was cheaper than Biasill. For many years, olivine had been used in foundries in Scandinavian countries, and considerable knowledge was available about its use. The SIR program agreed to contribute to a study, but additional support was needed, and the Pennsylvania Science and Engineering Foundation (PSEF) was approached. A cooperative proposal, ("An Investigation of the Feasibility of Reducing Respirable Free Silica in Foundry Operations by Sand Substitution") was submitted to PSEF involving $48,000 from PSEF, $21,333 from SIR and $7,500 from Mr. Martin and John Samuels of the Department of Industrial Engineering. The study involved blending Olivine and silica sand in varying amounts and monitoring the airborne free silica at work stations at which OSHA violations had been detected. The program also involved economic studies to assess the costs of blending. The proposal was declined.

Concurrent with these activities, Mr. Martin sought permission from OSHA to outfit workers with personal protective devices and pursued the matter through his Senator, Richard Schweiker. Exhibit 2 is a letter from the Secretary of Labor to Senator Schweiker affirming the need for engineering controls as the primary method of control. In October 1976, a cooperative research project (involving $13,000 from $24,418 from SIR, and $5,000 from Roaring Spring) was approved in which olivine was substituted for green sand in the no-bake molds and a series of air samples were to be taken for a 24-month period at points found to be in violation by OSHA. Technical personnel in the field could not agree upon a standard method to measure the free silica concentration. A method was developed by John Davis at Penn State based on the Bumstead X-Ray diffraction method (1).

RICHARD S. SCHWEIKER
PENNSYLVANIA

COMMITTEES:
APPROPRIATIONS
LABOR AND PUBLIC WELFARE
SELECT COMMITTEE ON
NUTRITION AND HUMAN NEEDS
TECHNOLOGY ASSESSMENT BOARD

United States Senate
WASHINGTON, D.C. 20510

JUN 4 1976

To: Mr. Stanley Martin, President
Roaring Spring Foundry.
Roaring Spring, PA

From: Dick Schweiker Dick
U.S. Senator

Enclosed is the reply I received to the inquiry I made in your behalf.

Because I have always felt constituents should be able to view their Senator as someone to whom they can turn at no cost for help, I was pleased you gave me this chance to try.

Should you feel there is anything further I can do, I hope you will not hesitate to let me know.

RSS:jd

EXHIBIT 2

U. S. DEPARTMENT OF LABOR
OFFICE OF THE SECRETARY
WASHINGTON

JUN 2 1976

Honorable Richard S. Schweiker
United States Senate
Washington, D. C. 20510

Dear Senator Schweiker:

This is in response to your letter of February 13, 1976, concerning the difficulties some employers are experiencing in their efforts to comply with the Occupational Safety and Health Administration's (OSHA) regulations. At the outset I would like to point out that a new OSHA National Emphasis Program is now under development to aid employers in their efforts to bring their work environment into compliance with safety and health regulations. This new concept is designed to stimulate and aid compliance with the Act through a combination of exhaustive compliance inspections, education, and to the extent permitted by law, consultative services advisement to interested employers. One of the first industries to be selected for this program is the foundry industry, in which your constituent is involved.

With respect to the concerns expressed by your constituent, I wish to begin by stressing that any reduction in the permissible exposure limit for crystalline silica dust will be pursuant to a determination by OSHA that exposure at the present limit constitutes a significant health hazard. Interested parties will, of course, be given an opportunity to comment by letter or to testify at an open hearing on any proposed revision before final promulgation. Carrying forward with the other concerns, I would point out that OSHA does not have a policy of imposing daily penalties on employers inadequately controlling harmful airborne agents (chemicals, noise, etc.) provided the employers are implementing approved engineering plans to abate the condition and provided would-be overexposed employees are afforded interim protection through the enforced use of personal protective equipment. It is our policy to require employers to make all engineering efforts technically feasible to bring employee exposure to harmful airborne agents within permissible limits. Where the state of the art of engineering controls is insufficient to totally bring

exposures within the permissible limits, OSHA requires that all feasible engineering controls be implemented to bring levels of exposure as close to the permissible limits as possible and that employers additionally provide and enforce the use of personal protective equipment to protect employees from the remaining hazard. I would note in response to your constituent's preference for the use of personal protective equipment alone that these devices afford far less than foolproof protection, are burdensome, and rely to a great extent upon positive employee participation which oftentimes cannot be assured. On balance therefore, engineering controls offer a much better long range approach to abating health hazards in the workplace airspace. Accordingly, as indicated above, OSHA has made the policy determination that personal protective equipment is to be used as a last resort in efforts to eliminate employee exposure to many extremely debilitating airborne agents.

In closing I would note that we recognize that the elimination of these types of hazards can require the expenditures of rather large sums of money by employers. However, such expenditures are absolutely necessary if the Congressional intent of assuring safe and healthful working conditions for employees is to be realized in the foundry industry and many other industries.

I appreciate your interest in this matter and hope that you find the contents of this letter of some assistance.

Sincerely,

W J Usery Jr.

Secretary of Labor

Though olivine is a well known mineral, its use in U.S. foundries was an innovation. The effects of olivine on human health were not known, and OSHA expressed an interest (Exhibit 3) in studying its toxicity. Adrian Zarkower, an animal physiologist at Penn State who was interested in the effects of pollutants on the immune system in humans and animals, became interested in olivine toxicology. As a member of the Center for Air Environmental Studies (CAES) at Penn State, he had pursued research in animal toxicology studies of flyash and other airborne contaminants in collaboration with John Davis. In January 1977, Dr. Zarkower was awarded a 1-year research grant from the Public Health Service ("Silica Dust Inhalation and Resistance to Infections.") Upon completing this work, he repeated the studies with olivine through a 2-year from International Mineral Company in August 1980.

Switching to olivine at the Roaring Spring Foundry reduced the airborne free silica concentrations, but the grinding room remained out of compliance with the OSHA standards. In addition, the quality of the castings improved significantly. Surface imperfections produced by silica sand were reduced markedly because the thermal expansion properties of olivine were superior to silica sand. In May 1977, John Samuels presented a paper on these results at a meeting of the American Foundrymen's Society (2). In May 1978, a second paper on these studies was presented at the annual meeting of the American Industrial Hygiene Association by John Davis (3). These papers produced considerable interest and led to the publication of shorter articles in trade journals (for example, Exhibit 4). Silica sand continued to be used in the foundry for cores and no-bake operations; but as these operations could be segregated from the use of olivine, it was assumed that segregation of the two materials could be maintained. The assumption proved to be false. Throughout 1977 and 1978, the proportion of silica sand mixed with the olivine increased; the airborne free silica concentration increased steadily, and the surface quality of the castings worsened.

The research environment in CAES that aroused the interest of Adrian Zarkower also affected Robert Heinsohn, a mechanical engineer whose experience in research, teaching, and consulting was in the field of air pollution. At an earlier time, Robert Heinsohn became aware of deficiencies in the technology of controlling contaminants in the workplace, and he became interested in the problems at the foundry. Existing industrial ventilation technology was not necessarily wrong, but it was primitive and lacked generalized principles that would enable engineers to control contaminants from a variety of sources. In addition, Robert Heinsohn received a research grant from NIOSH to study the effectiveness of grinding booths for large castings. The outcome of the research were computer programs that computed the trajectories of particles and the particle concentrations at arbitrary points inside the booth (4-6).

In February and March 1979, OSHA returned to inspect the foundry

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration
WASHINGTON, D.C. 20210

Health Response Team, OSHA
390 Wakara Way
P.O. Box 8137
Salt Lake City, UT 84108

June 10, 1977

John M. Samuels, Ph.D.
Industrial Engineering Department
Pennsylvania State University
University Park, PA 16802

Dear Dr. Samuels:

I read with interest in the Industrial Hygiene News Report (May, 1977), that you are planning some investigations on olivine.

I have also looked into the toxicology of olivine and its feasibility as a silica substitute. Enclosed for your information is a letter from the Assistant Secretary for Occupational Safety & Health, Department of Labor to the Director of the National Institute for Occupational Safety & Health (NIOSH), requesting that NIOSH conduct a toxicological evaluation of this substance. Also enclosed is my initial review.

We would certainly appreciate any further information you may have on this substance and look forward to the results of your investigation.

Sincerely yours,

Jeffrey S. Lee
Assistant Director,
Health Response Team

2 Encls.

EXHIBIT 3

MAY 16 1977

Dr. John F. Finklea, Director
National Institute for Occupational
Safety and Health
Park Building, Room 3-30
5600 Fishers Lane
Rockville, Maryland 20352

Dear Dr. Finklea:

Olivine, a Magnesium Iron Silicate, (MgFe)2 SiO4, is currently being used in the foundry industry as a silica substitute. The Registry of Toxic Effects of Chemical Substances (1976), designates olivine as a neoplastic agent citing an animal experiment conducted by Davis in 1972 (Brit. J. Exp. Path., 53:190, 1972).

Our preliminary review of the few reported studies on this substance has revealed a lack of agreement on the fibrogenicity of olivine. Some studies report that olivine is slightly fibrogenic, others report that it is not fibrogenic. When free silica is present in olivine it is usually within the range of 3 to 5%; on this basis olivine is less toxic than silica. More long-term inhalation studies are needed to properly assess the toxicity of olivine. Currently OSHA does not have a standard for this mineral, nor have any other organizations or countries established or suggested a standard to our knowledge. At this point, the material appears to be not only safer than silica but also a technically feasible alternative to silica in foundries and perhaps other industrial situations. As OSHA is now engaged in an extensive foundry inspection program as a part of the National Emphasis Program, we are very interested in obtaining an accurate assessment of the potential toxicity of olivine. I would, therefore, like to request that NIOSH begin a toxicological evaluation of this substance as soon as possible. Enclosed for your information is our preliminary review.

If you have any questions concerning this matter, please contact Mr. B. K. Kwon, 523-7741.

Sincerely,

Eula Bingham

Eula Bingham
Assistant Secretary
Occupational Safety and Health

Enclosure

OFCF:CARoman:atb:5/9/77:Rm.N3603-Ext. 37763
cc: Bingham/Lake/Kwon/Kelleher/Jeff Lee SLC/Roman
Chron. File/atb

Jeff Lee

EXHIBIT 3.1

OLIVINE SAND APPEARS TO BE A WINNER

***Editor's Note:* Research and Development for Industry** *reports the results of completed and continuing investigations sponsored by Penn State's Small Industries Research program. This program is based in the Office of the Vice President for Research and Graduate Studies, 207 Old Main, University Park, PA.*

Graduate students play a large role in research sponsored jointly by Small Industry Research (SIR) and industry. These projects, like most other sponsored research projects conducted at Penn State, are planned to include topics suitable for graduate thesis work. The student gains the opportunity to complete a thesis, usually part of the advanced degree requirements, and the faculty member gains valuable manpower.

Many opportunities for graduate thesis work exist in basic as well as applied research. Students who wish to earn an advanced degree working in a cooperative industrial-academic setting and those industrial scientists and engineers who wish to return to school for the same purpose are invited to contact James W. Lundy, Manager, Small Industries Research, The Pennsylvania State University, PA 16802, or call (814) 865-9519. Questions about other research opportunities will be referred to appropriate sources.

This article is a sample of the work done and published by the University.

A new molding sand for metal casting, up to five times as expensive as the traditional silica sand, may save money for foundries and help them stay in business.

If that seems contradictory, it is. But three Penn State faculty members and management and workers at the Foundry, PA. are quick to point out the advantages of olivine sand for molds. And an initial large expenditure makes a lot of sense if fewer molding additives, better casting quality, less metal scrap, less make-up sand to buy, and less silica dust in the air are the advantages.

Olivine sand is crushed, refined, and sized mineral rock quarried from North Carolina and Washington State deposits. "The purest olivine," says industrial engineer John M. Samuels, Jr., "is said to come from Washington." This complex silicate of magnesium and iron isn't nearly as quick as silica sand to release airborne silica particles of a size easily trapped in lungs. Dr. Samuels, the principal investigator on this project, says silica reduction and rising silica sand prices were the stimulants leading to this study.

Samuels says the secret of olivine is that very little new sand needs to be added as molding sand is reused. Because olivine sand breaks down less quickly than silica sand, it stands up better under casting conditions. As, fines—very small sand particles—accumulate in molding sand, casting quality falls off, since gases generated when hot metal is poured into the mold can't escape through the sand.

Normally, foundry workers must discard a certain percentage of old sand, replace it with new, and in a silica sand system must continually add combustibles and other materials to bind the sand into the desired shape and to keep hot metal from sticking to the sand. Any decrease in make-up sand and in additive usage, which olivine promises, saves time and money. Samuels points out that in five months of casting at there was an increase in fines of only about 10 AFS numbers and very little new sand was added in about four months of operation.

But economics aside, there's an even more important reason for this joint Industry-University experiment. It began as a test of the ability of olivine sand systems to reduce respirable silica, a dust responsible for silicosis. In 1973 the state legislature removed the maximum benefit limit paid to silicosis victims, and coverage for silicosis claims was subsequently discontinued by a private firm insuring 70% of Pennsylvania foundries for this disability. This crisis, plus OSHA silica standards, has jeopardized the existence of some of the 390 Pennsylvania foundries employing an estimated 41,255 workers (American Foundrymen's Society statistics as of December 31, 1976). Other sources estimate an annual $350 million payroll from this industry.

"Our task was to find the least cost solution to bring respirable free silica content of the air down to levels acceptable by the American Conference of Governmental Industrial Hygienists and OSHA," says Samuels. He, John W. Davis, Robert Lawrence of the University's Center for Air Environment Studies, and mechanical engineer Robert J. Heinsohn collaborated on the work. They sampled air at various work stations of the Foundry before and after the changeover from silica to olivine sand. Foundry president superintendent and health and safety coordinator, were most cooperative.

According to Samuels, OSHA inspectors in 1973 found five work areas in violation of standards of silica and several borderline cases when silica sand was the entire molding medium. Penn State sampling, more rigorous than OSHA's but in accord with their methods, uncovered 10 violations and several borderline cases. After the changeover to olivine, the only violation found was in the portable grinding area. There is some evidence that this silica carryover came from silica sand core molding operations. At silica sand still plays a part in no-bake molds and certain core operations where chemical additives make olivine usage impractical.

Samuels says that the prospect of silica contamination of olivine molding operations is one facet that needs to be studied. But he says that better separation of silica molding opera-

EXHIBIT 4

tions from the olivine stations would help to solve that problem.

In a paper by Davis, Samuels, Marcus, and Lawrence is a sentence that perhaps best summarizes the work: "The study revealed that a switch to olivine will reduce the free silica levels enough to meet OSHA standards when contamination from silica sand no-bake cores and molds is controlled." The paper, "Meeting OSHA Silica Air Quality Standards by Sand Substitution," was presented by Samuels at the National Congress of the American Foundrymen's Society in April 1977. Copies of the paper can be obtained by writing to the Center for Air Environment Studies, 226 Fenske Lab, University Park, PA 16802, and asking for CAES Publication No. 467-77.

Mr. , is sold on olivine sand, and he says he would change to it even if there were no silicosis problem. "And that," he says, "may not mean much to non-foundry people, but it does to those aware of the high initial cost of olivine."

is especially impressed with surface finish of parts cast in olivine. "Expansion defects have been cut; we have virtually none," he says. "The olivine sand supplier has been most cooperative, and his claims for the product have held true. We bought 100 tons of sand; replaced 70 tons of silica sand and kept 30 tons as make up."

Most of the 50 employees also prefer the olivine sand to silica. They claim it is less dirty and gritty than silica sand and they don't need to scrub as hard in the shower to remove it. For those people who haven't walked through a foundry or worked in one, this might not mean as much as it does to those who spend eight hours or more among the inevitable dust from molds, metal powder from grinding operations, fumes from hot metal, and grit from sand blasting operations.

pours from 10 to 15 tons of gray and ductile iron each day to make large electrical distribution boxes, small castings, and old fashioned fluted lampposts. As superintendent said while he watched a Victorian style iron lamppost being poured, "The Bicentennial year was good for business."

Foundries, because of casting methods, may be rather dirty places to work in, but they have been and still are a very necessary part of the economic life of small towns. Some fifty Commonwealth foundries have closed in the past few years, a blow to the economy Pennsylvania can ill afford. Buying expensive dust collecting equipment, especially when it might not reduce airborne silica levels to OSHA's standards as some foundries have found, is an experience this industry doesn't need.

Foundry contributed both time and money to support the project, as do all companies participating in SIR projects.

EXHIBIT 4.1: Taken from <u>The Small Manufacturer</u>
Vol. 34, No. 1, January 1979.

and issued several citations for violations (Exhibit 5). Free silica violations were found for grinders and two bench molders. The free silica concentrations reported by OSHA were considerably higher than those measured by John Davis. Because of these discrepancies and the effort of the foundry to achieve compliance and participate in numerous research studies, Mr. Martin appealed to the Occupational Safety and Health Review Commission. The Commission reviewed the case and rescinded all citations except those regarding violations in the use of forklift trucks.

CITATION and NOTIFICATION OF PENALTY

Suite 4256 - Federal Building
600 Arch Street
Philadelphia, Pennsylvania 19106
(215) 597-4955

[illegible]	
Serious	1

8/17/79		
REGION	AREA	PAGE
3	6540	1 OF 5

INSPECTION DATE:
1/30/79 - 5/22/79

INSPECTION SITE:

TO:

THE LAW REQUIRES that a copy of this Citation be posted immediately in a prominent place at or near the location of the violation(s) cited below. The Citation must remain posted until the violations cited below have been corrected, or for 3 working days (excluding weekends and Federal holidays) whichever is longer.

PENALTIES ARE DUE WITHIN 15 DAYS OF RECEIPT OF THIS NOTIFICATION UNLESS CONTESTED (See enclosed Booklet)

This Section to Be Detached Before Posting

This citation describes violations of the Occupational Safety and Health Act of 1970. The penalty(ies) listed below are based on these violations. You must correct the violations referred to in this citation by the dates listed below and pay the penalties proposed, unless within 15 working days (excluding weekends and Federal holidays) from your receipt of this citation and penalty you mail a notice of contest to the U.S. Department of Labor Area Office at the address shown above. (See the enclosed booklet which outlines your responsibilities and courses of action and should be read in conjunction with this form.)

ITEM NUMBER, STANDARD, REGULATION OR SECTION OF THE ACT VIOLATED: DESCRIPTION	DATE BY WHICH VIOLATION MUST BE CORRECTED	PENALTY
The violations described in this citation are alleged to have occurred on or about the day the inspection was made unless otherwise indicated within the description given below.		
1a 29 CFR 1910.95(a): Protection against the effects of noise was not provided for employee(s) exposed to sound levels which exceeded those listed in Table G-16 of Subpart G of 29 CFR Part 1910: a) Lower Grinding Room — Cut-off Man; employee operates large and small cut-off saws. (observed 2/28/79)	STEP 1 Immediately	$900
1b 29 CFR 1910.95(b)(1): Employee(s) were subjected to sound levels exceeding those listed in Table G-16 of Subpart G of 29 CFR Part 1910 and feasible administrative or engineering controls were not utilized to reduce sound levels: a) Lower Grinding Room — Cut-off Man. (observed 2/28/79) b) Grinding Room — Grinders (three); employees operate portable pneumatic grinders. (observed 2/28/79) STEP 1 - Effective personal hearing protection shall be provided and used by employee(s) as an interim protective measure. STEP 2 - A written detailed plan of abatement leading to the complete abatement of this item shall be submitted to the Area Director. Such a plan shall: a) employ the use of qualified engineering personnel; b) include detailed engineering studies and their results; c) outline the ordering of equipment and materials and completion of the design phase; and d) outline dates for the anticipated implementation of the plan. STEP 3 - Feasible engineering controls and/or administrative controls shall be determined.	STEP 2 10/20/79 STEP 3 12/20/79 STEP 4 4/20/80	

CITATION and NOTIFICATION OF PENALTY

Suite 4256 - Federal Building
600 Arch Street
Philadelphia, Pennsylvania 19106
(215) 597-4955

TYPE OF VIOLATION(S)	[illegible]
Serious	1

ISSUANCE DATE	OSHA NUMBER	
8/17/79		
REGION	AREA	PAGE
3	6540	2 OF 5

INSPECTION DATE:
1/30/79 - 5/22/79

INSPECTION SITE:

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ITEM NUMBER STANDARD, REGULATION OR SECTION OF THE ACT VIOLATED: DESCRIPTION	DATE BY WHICH VIOLATION MUST BE CORRECTED	PENALTY
STEP 4 - Abatement shall be completed by the implementation of feasible engineering controls and/or administrative controls and its effectiveness at achieving compliance verified. Sixty-day progress letters are requested during the abatement period.		
1c 29 CFR 1910.95(b)(3): A continuing, effective hearing conservation program was not administered in all cases where sound levels exceeded permissable levels, in that: (1) employees were not fit tested for hearing protection nor were they provided instruction in the proper use of hearing protection; (2) base line audiograms were not administered; (3) there is no provision for administration of periodic audiometric testing, and (4) there is no provision for referral to a physician of employees whose audiograms may show a 20 dB hearing loss in any frequency: a) Lower Grinding Room — Cut-off Man. (observed 2/28/79) b) Grinding Room — Grinders. (observed 2/28/79)	9/20/79	
2a 29 CFR 1910.134(a)(2): The employer did not establish and maintain a respiratory protection program which included the requirements outlined in paragraph (b) of this section: a) Grinding Room — Employees operating portable, pneumatic grinders are required to wear 3M "White Cap" supplied air respirators. (observed 3/1/79)	9/3/79	$720
2b 29 CFR 1910.134(b)(1): Written standard operating procedures governing the selection and use of respirators were not established: a) Grinding Room — Employees operating portable, pneumatic grinders are required to wear 3M "White Cap" supplied air respirators. (observed 3/1/79)	9/3/79	

EXHIBIT 5.1

Suite 4250 – Federal Building
600 Arch Street
Philadelphia, Pennsylvania 19106
(215) 597-4955

TYPE OF VIOLATION(S)	NUMBER
Serious	1

3	6540	3 OF 5

INSPECTION DATE:
1/30/79 – 5/22/79

INSPECTION SITE:

TO:

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ITEM NUMBER / STANDARD, REGULATION OR SECTION OF THE ACT VIOLATED: DESCRIPTION	DATE BY WHICH VIOLATION MUST BE CORRECTED	PENALTY
2c 29 CFR 1910.134(b)(5): Respirators were not regularly cleaned and disinfected: a) Grinding Room — Employees operating portable, pneumatic grinders are required to wear 3M "White Cap" supplied air respirators. (observed 3/1/79)	Immediately	
2d 29 CFR 1910.134(b)(6): Respirators were not stored in a convenient, clean and sanitary location: a) Grinding Room — Employees operating portable, pneumatic grinders are required to wear 3M "White Cap" supplied air respirators. (observed 2/28/79).	Immediately	
2e 29 CFR 1910.134(b)(7): Respirators used routinely were not inspected during cleaning and worn or deteriorated parts replaced: a) Grinding Room — Employees operating portable, pneumatic grinders are required to wear 3M "White Cap" supplied air respirators. (observed 2/28/79)	Immediately	
2f 29 CFR 1910.134(b)(9): There was no regular inspection and evaluation to determine the continued effectiveness of the respirator program: a) Grinding Room — Employees operating portable, pneumatic grinders are required to wear 3M "White Cap" supplied air respirators. (observed 2/28/79)	9/3/79	
2g 29 CFR 1910.134(b)(10): Persons were assigned to tasks requiring use of respirators and it had not been determined that they were physically able to perform the work and use the equipment, and the respirator user's medical status was not reviewed periodically (for instance annually): a) Grinding Room — Employees operating portable, pneumatic grinders are required to wear 3M "White Cap" supplied air respirators. (observed 2/28/79)	9/20/79	

EXHIBIT 5.2

CITATION and NOTIFICATION OF PENALTY

Suite 4256 - Federal Building
600 Arch Street
Philadelphia, Pennsylvania 19106
(215) 597-4955

[illegible]	[illegible]
Serious	1

8/17/79		
REGION	AREA	PAGE
3	6540	4 OF 5

INSPECTION DATE:
1/30/79 - 5/22/79
INSPECTION SITE:

TO:

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ITEM NUMBER STANDARD, REGULATION OR SECTION OF THE ACT VIOLATED: DESCRIPTION	DATE BY WHICH VIOLATION MUST BE CORRECTED	PENALTY
3a 29 CFR 1910.178(l): Operators were not trained in the safe operation of powered industrial trucks: a) In Main Foundry and Yard. (observed 2/28/79)	Immediately	$720
3b 29 CFR 1910.178(m)(3): Unauthorized personnel were permitted to ride on industrial truck(s): a) Main Foundry — Employee was observed riding on fork while vehicle was in motion. (observed 2/28/79)	Immediately	
3c 29 CFR 1910.178(m)(12): Industrial truck(s) used to lift personnel were not provided with a firmly secured safety platform and a means whereby personnel on the platform could shut off power to the truck: a) No Bake Area — Employee observed cleaning no-bake mixer from elevated fork of lift truck. (observed 2/28/79) b) Floor Molding Area — Employee observed repairing overhead hoist from elevated fork of lift truck. (observed 2/28/79) The combination of the above alleged violations, when viewed collectively, result in a serious classification of the violation.	Immediately	
4a 29 CFR 1910.1000(c): Employee(s) were exposed to material(s) in excess of the 8-hour time weighted average limit(s) listed for that material(s) in table Z-3 of subpart Z of 29 CFR part 1910: a) Respirable Crystalline Silica (Quartz); Grinding Room — Three grinders using portable pneumatic grinding tools. (observed 3/1/79)	8/20/80	$900

EXHIBIT 5.3

CITATION and NOTIFICATION OF PENALTY

Suite 4256 - Federal Building
600 Arch Street
Philadelphia, Pennsylvania 19106
(215) 597-4955

Serious	1

8/17/79		
REGION	AREA	PAGE
3	6540	5 OF 5

INSPECTION DATE:
1/30/79 - 5/22/79
INSPECTION SITE:

TO:

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ITEM NUMBER STANDARD, REGULATION OR SECTION OF THE ACT VIOLATED: DESCRIPTION	DATE BY WHICH VIOLATION MUST BE CORRECTED	PENALTY
4b 29 CFR 1910.1000(e): Feasible administrative or engineering controls were not determined and implemented to reduce employee exposure(s): a) Respirable Crystalline Silica (Quartz); Grinding Room — Three grinders using portable pneumatic grinding tools. (observed 3/1/79) STEP 1 - A written detailed plan of abatement leading to the complete abatement of this item shall be submitted to the Area Director. Such a plan shall: a) employ the use of qualified engineering personnel; b) include detailed engineering studies and their results; c) outline the ordering of equipment and materials and completion of the design phase; and d) outline dates for the anticipated implementation of the plan. STEP 2 - Feasible engineering controls and/or administrative controls shall be determined. STEP 3 - Abatement shall be completed by the implementation of feasible engineering controls and/or administrative controls and its effectiveness at achieving compliance verified. Sixty-day progress letters are requested during the abatement period.	STEP 1 10/20/79 STEP 2 12/20/79 STEP 3 8/20/80	

EXHIBIT 5.4

CITATION and NOTIFICATION OF PENALTY

Suite 4256 - Federal Building
600 Arch Street
Philadelphia, Pennsylvania 19106
(215) 597-4955

ISSUANCE DATE	OSHA NUMBER	
8/17/79		
REGION	AREA	PAGE
3	6540	1 OF 1

[illegible]	
Other	2

INSPECTION DATE:
1/30/79 - 5/22/79

INSPECTION SITE:

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The violations described in this citation are alleged to have occurred on or about the day the inspection was made unless otherwise indicated within the description given below.		
1 29 CFR 1910.22(a)(1): Place(s) of employment were not kept clean and orderly, or in a sanitary condition: a) Lower Grinding Room — Metal castings were strewn on floor around small cut-off saw in well trafficked passageway near outside door causing tripping hazard. (observed 2/28/79) b) Grinding Room — Passageway through Grinding Room partly obstructed by stored lampposts and other metal castings. (observed 2/28/79) c) Main Foundry Room, Cleaning Area — Passageway from Wheelabrater to abrasive blasting room obstructed with trash and metal castings causing tripping hazard. (observed 2/28/79) d) Main Foundry Room, No Bake Pouring Area near Brass Furnace — Passageway to outside door is blocked with trash, cores and castings causing tripping hazards and preventing easy access to exit. (observed 2/28/79)	Immediately	$0
2 29 CFR 1910.94(a)(3)(i)(a): All access openings were not baffled or so arranged that by the combination of inward air flow and baffling the escape of abrasive or dust particles into an adjacent work area would be minimized and visible spurts of dust would not be observed: a) Cleaning Department, Blasting Booth — Visible dust was observed escaping through windows (two), and ceiling opening for hoist track. (observed 2/28/79)	Immediately	$0

ABSTRACT

A case study is presented to describe the Roaring Spring Foundry's attempt to achieve compliance with Occupational Safety and Health Administration (OSHA) standards for free silica and noise, which the company was cited for violating in 1973 and 1979. This small gray iron foundry in eastern Pennsylvania manufactures decorative Victorian lamp posts, junction boxes, and other electrical equipment for exterior lighting. Compliance with the OSHA standards was attempted through the substitution of olivine for silica sand, the use of personal protection equipment, and the development of a grinding booth for large castings. The case study addresses the following items: (1) the toxicology of silica and olivine, (2) economic analysis of using olivine sand and/or engineering controls, (3) measurement of airborne free silica, and (4) engineering controls. Included is discussion on the attitudes and thoughts of the company president, who sought help from professional societies, a research university, state and federal agencies, and other foundries in Pennsylvania to respond to the OSHA Foundry Emphasis Program that targeted the foundry industry for cleanup in the 1970's.

INSTRUCTOR'S NOTE

Table of Contents

PART II - INSTRUCTORS NOTE

The case study contains several components. It is important that readers understand what the case study intends to achieve. Once understood the reader can improvise and achieve any number of other objectives. Students should learn:

(1) How to find which OSHA standards apply to a process and how measurements are made to ascertain if the standards are met;

(2) How to satisfy OSHA standards by substituting materials, personal protective devices or engineering controls;

(3) How to perform economic analyses to determine the cost and pay-back period associated with different methods of compliance;

(4) How to apply state-of-the-art industrial ventilation technology to design engineering controls;

(5) How industrial managers interact with professional organizations, academic institutions, regulatory agencies and the judicial review process;

(6) How the solution to one industrial problem is apt to reveal inadequacies in technological knowledge;

(7) How engineers exchange and disseminate technical information; and

(8) How research is initiated.

Successful design education turns on creating an authentic environment in which students cope with limited time, money, materials and manpower yet make decisions leading to the creation of a device or process that satisfies certain performance specifications. Engineering design projects are emotionally stimulating experiences in which students personally create devices and systems and demonstrate their efficacy in a student competition. Projects suffer from the fact that they are conducted in a university setting, where they may degenerate to tinkering or "fun and games," which may be exciting and personally satisfying but may also be amateurish. Such projects are long on motivation but short on industrial authenticity.

On the other hand, case studies are unquesionably authentic, since they are accounts of industrial developments that actually occurred. They are effective ONLY if they engage the student's mind and imagination. Case studies suffer from the fact that they are vicarious experiences whose value depends on the student's ability to read. Case studies are effective for students who have facility with

language. In prestigious institutions with stringent entrance standards (particularly high SAT verbal scores), case studies can be used easily and effectively. In institutions where the SAT verbal scores are lower and the students' communication skills poorer, instructors must devise unique and special ways to engage students. The usefulness of case studies cannot be taken for granted. All too often an instructor finds a case study absolutely stimulating the students consider it boring. Instructors forget that they are 10 to 20 years older than the student and that its the instructor's maturity that makes the case study stimulating.

Further complicating the matter is the fact that institutions whose students have lower verbal skills are often those in which the design class is large and where there is little personal involvement with students. Nevertheless, if instructors are careful and clever, they will find that case studies are effective ways to teach occupational safety and health aspects of engineering design.

The case study is in two parts: Part I is the narrative account of actions taken by the company, and Part II is the Instructors Note, which suggests ways to use the case study. The latter section provides factual information about four aspects of the issue:

Section 1 - Toxicology,
Section 2 - Engineering Economics,
Section 3 - Air Quality Survey,
Section 4 - Engineering Controls.

Each section ends with a set of study questions illustrating information in the section. Instructors should devise additional questions as the mood moves them. Background information is provided in the form of figures, tables, and attachments so that instructors can devise problems and questions that may arise spontaneously.

Section 1 concerns the subject of toxicology and conveys facts about silicosis and why respirable silica dust is a serious workplace hazard. Section 1 also shows that the OSHA citations the foundry received pertained to substantive issues and not bureaucratic pettiness or harassment.

Section 2 concerns engineering economics and presents the rational way industrial engineers advising the foundry compared the cost of proposals to substitute different amounts of olivine for silica sand. Using this information, readers can compute the cost of solutions ignored by the foundry. The instructor must carefully point out that the cheapest method is merely a calculation, and if all factors are not included in the computation, the result may be irrelevant. The instructor should ask students to identify important factors omitted from the economic model, since factors that cannot be quantified may be as important (or more) than those that can be quantified. In short, the best method may not be the one that is computed to be the cheapest.

Section 3 contains information about how silica concentrations were measured in the foundry and the factors that produced uncertainty in these measurements. Compliance with OSHA standards is determined on the basis of measurements. Students must therefore learn that if the difference between the measured values and the OSHA standards is less than the experimental uncertainty, individuals are apt to ascribe unwarranted significance to numbers and arrive at wrong conclusions. Because of these uncertainties, the company was successful in appealing to the Occupational Safety and Health Commission to rescind the citations.

Section 4 describes the engineering controls that were considered by the company, the costs of each, and the reasons for developing a new type of ventilation system for a grinding booth.

A. Section 1 - Toxicology

Under the Occupational Safety and Health Act of 1970, it is the responsibility of the Secretary of Health and Human Services to ". . . develop criteria dealing with toxic materials and harmful physical agents and substances which will describe . . . exposure levels at which no employee will suffer impaired health or functional capacities or diminish life expectancy as a result of his work experience." The purpose of this section is to describe the effects that crystalline silica and olivine sand have on health. An excellent discussion of the health effects of crystalline silica and olivine can be found in references 7 and 8 and in Exhibit 6.

Silicon dioxide (SIO2) exists as either quartz, tridymite, or cristobalite. Quartz is a material that may be colorless, white, smoky, rose, violet brown, or almost any hue, depending on impurities. Quartz may either be crystalline in structure or amorphous (noncrystalline). Tridymite is a white or colorless platy orthohombic crystal formed when quartz is heated above 870°C. Cristobalite is a white, cubic-system crystal formed by heating quartz above 1470°C. Tridymite and cristobalite usually occur together.

Silicosis is a nodular pulmonary fibrosis caused by the inhalation and deposition of particles of free silica in the pulmonary system. The disease is also called a variety of familiar names, such as dust consumption, grinder's rot, mason's disease, miner's asthma, stonemasons's disease, and several others. The disease was identified and diagnosed in the early 18th century, although reference to stonemason's disease can be found in the literature of ancient Rome. The fibrosis nodules impede pulmonary function, which reduces stamina, stresses the heart, and is generally debilitating. Strictly speaking, silicosis is not an immediate cause of death, but it may be the contributing factor that triggers the immediate cause of death.

"HEALTH ASPECTS OF OLIVINE: PROGRESS REPORT NO. 1"

George E. Tubich

SUMMARY:

In preventing most occupational diseases one of the factors considered is the substitution of a less toxic material. This was not a simple achievement for the foundry industry. Olivine, which contains no free silica, has been introduced as a substitute for silica sand. The use of silica sand cores, bentonite and clays and other additives containing free silica will bring about a certain degree of contamination to the olivine. However, these levels of contamination are considerably below the free silica values found in conventional foundry operations. Dust concentrations and particle-size distribution are in the same order of magnitude in foundries using either olivine or silica sand. Dust control, by well engineered ventilation systems, is still a necessity. Animal investigations, through inhalation and intratracheal injection, show that the reaction to olivine is one of a simple foreign body type response. The proper application of olivine as a molding material may play an important role in reducing the incidence of silicosis.

I. INTRODUCTION

Silicosis, a disease as old as industry itself, has not been eliminated. Although recent studies indicate a definite reduction in its prevalence, today, despite the tremendous amount of research conducted throughout the world, silicosis still continues to be the major occupational disease with respect to disability and compensation.

In preventing most occupational diseases a properly designed system of exhaust ventilation is usually one of the first methods considered. Among others is the substitution of a less toxic material. With respect to the foundry industry there is no question that proper dust control is still the best method. The idea of a substitute, a practical non-siliceous molding material, has been a long-sought dream. Now, a non-siliceous molding material, olivine, has been introduced to the industry. Olivine contains no free silica and with proper application may play an important role in reducing the incidence of silicosis.

II. CHEMISTRY, MINERALOGY AND OCCURRENCE

The mineral olivine was first described by J. G. Werner in 1790 and was named olivine because of its olive-green color. It is a natural mineral consisting of two end members—magnesium orthosilicate (fosterite—Mg_2SiO_4) and iron orthosilicate (fayalite—Fe_2SiO_4), and the intermediate isomorphous mixture olivine ($(Mg, Fe)_2SiO_4$), of which dunite, a monomineralic rock of the peridotite class, is composed.

Fosterite, the magnesian end member of the olivine group, is rarely found alone. Its color is white, greenish, or yellow; hardness 6-7 and a specific gravity, 3.21-3.33.

Fayalite, the iron end member, like fosterite is rarely found alone. It is usually light greenish yellow but may be brown or black, owing to oxidation; hardness, 6.5; and specific gravity, 4.1.

Olivine, usually occurs in granular masses or disseminated crystals and grains. Its color is yellowish to olive-green, but, owing to the oxidation of iron, may be brown, greyish, or red; hardness 6.5-7; and specific gravity 3.27-3.37. Olivine is basic and has a pH in the range of 8 to 9.

The composition of olivine may vary and only those with the highest fosterite content are useful as foundry materials. Olivine aggregates are produced from the olivine bearing rock known as dunite. Dunite consists essentially of even-grained crystalline olivine with minor amounts of chromite disseminated through the mass as well as occasional grains of pyroxene. Typical average chemical and mineralogical composition and other properties is shown in Table 1.

The mineral olivine and chrysolite are the same. There is, however, some confusion which might arise when using the term olivine since there is an olivine group of minerals. The members of the olivine group are: fosterite, fayalite, olivine (chrysolite) and tephroite. Only one of these minerals, chrysolite, is properly identified by the name olivine, but all are members of the olivine group.

The most suitable deposits of olivine for foundry applications are found in the western Cascade Mountain area of Washington State and the Great Smoky Mountain area of western North Carolina. These deposits are in the form of massive minerals that must be quarried, crushed, milled and classified into various size fractions in order to produce a suitable molding aggregate.

Production of olivine for industrial uses in the United States began in North Carolina on a very small scale in 1930. The production figures for 1932 were 720 short tons. Foundry usage for 1962 was 20,000 tons, 1967 about 50,000 tons and an estimated 60,000 tons by 1972. Fifteen to twenty percent of these values are in the form of olivine flour.

III. FOUNDRY APPLICATION

Olivine has been used as a raw material in certain basic refractories for over 30 years, but its significant applications as a foundry aggregate does not go beyond 15 years in the United States and about 25 years in Europe. The Scandinavians were the first to realize the advantages of olivine as a molding aggregate through investigations made to develop uses of large deposits in Norway.

The first recorded attempt at using crushed olivine as a molding aggregate was in a Norwegian steel foundry in 1927. In the United States research was carried out at the University of Washington in 1927, and in the early 1930's limited work was carried out at east-coast and midwest foundries.

Until 1938 only a few cases of silicosis were known in Norwegian foundries, but in that and the following year many foundry workers were X-rayed. Silicosis was found to such a degree that it called for remedies. Among other items under study was the use of a non-siliceous material as a molding media. Because olivine contains silicon dioxide combined with MgO and in smaller proportions, it was presumed that the risk of using olivine as a molding aggregate was not as great as using pure silica sand. Based on this presumption, along with considerable animal investigation involving exposure to olivine dust the Norwegian foundries began intensive use of olivine to reduce the silicosis hazard.

EXHIBIT 6

Excerpts from G.E. Tubich "Health Aspects of Olivine: Non-Ferrous Foundry Applications" (9)

In the United States a west coast steel foundry began an intensive investigation of the use of olivine in 1952 and in the Fall of 1953 began commercial production of manganese steel castings in olivine molds. Today, there are approximately 150-160 foundries in the United States and Canada using olivine molding systems. Another 300-400 foundries are using olivine on some type of limited or special application.

Olivine molding aggregate is used in both ferrous and non-ferrous foundries. However, currently its largest use is in aluminum, brass and bronze foundries followed by high manganese steel and grey iron.

There is an increasing application in the use of olivine flour for mold and core washes. These washes can be used with either a water or volatile carrier.

As a foundry aggregate olivine is most noted for its low constant coefficient of expansion, high thermal conductivity and heat absorption, high initial chill of casting skin, high specific gravity, low ignition loss and a reduction in the amount of additives required.

Olivine has been successfully used in green and dry sand molding, cores, and with the CO_2, shell, and certain no-bake or air-set processes. To date, it has not found satisfactory use with the Furan type resins. Other applications are for ladle linings and as an abrasive in blasting.

The cost of olivine is approximately 4 to 5 times that of ordinary silica sand. In addition to its potential of reducing the risk of silicosis the higher price of olivine is further compensated by savings made on cleaning room costs and other operations. Also, olivine has a longer life because of its thermal characteristics it undergoes only slight changes of grain size. Actually, it improves in quality with use, owing to the gradual reduction of its gas content.

IV. ENVIRONMENTAL DATA

During the past 5 years a study was undertaken to determine the contribution of olivine to the foundry environment and to learn whether the basic composition of olivine is significantly altered by the use of other materials containing free silica. At the time of this study period olivine was used only in non-ferrous foundries. Therefore, this study data represents the application of olivine in non-ferrous casting operations only. Its use in the ferrous industry will be reported on at a later date.

Involved in this study were 9 non-ferrous foundries with an employment range of 8 to 114 employees and a total employment of 394. Metals cast were aluminum, brass, bronze, and pure copper. Total amount of the metals poured per day was 61,000 pounds. In all instances the use of olivine was limited to its use as a molding aggregate. Cores were of silica sand and prepared by the CO_2, shell or oil-bake process.

Usual non-ferrous molding sand practices involves a silica sand that contains an average of 60-80 percent free silica. Silica core sands have a free silica content of 80-85 percent. The chief additives are southern and western bentonite that have a free silica content of 0-10 percent. Normal parting compounds are of the non-silica or liquid types.

Free Silica in Molding Aggregate and *Air-Borne Dust*—When new olivine is introduced into the foundry, its free silica content is usually less than one percent. While any silica bearing material that is added to olivine will cause a minor degree of contamination the main contaminant is the silica core. During the first 3 to 6 months there is a rapid build-up or contamination of the olivine with silica sand from the cores. This level slowly rises for another 6 months and then levels off. The maximum level will vary with each foundry and will be, in part, dependent upon the ratio of silica sand cores to the olivine.

The air-borne free silica values follow the same pattern and will generally be in the order of 40 percent below the amount found in the parent material. These values are shown in Table 2.

A comparison of the air-borne free silica values in foundries using olivine and others using silica sand is given in Table 3. The air-borne free silica values in foundries using olivine is almost 80 percent less than in silica sand foundries.

It was suspected that due to time and temperatures the layer of olivine at the mold-metal interface might undergo modifications that would result in the development of free silica, tridymite or cristobalite. This study and others[1] reveal no such modifications to be present.

Particle-Size Distribution—This was determined for the molding and shakeout operations. While these samples were not collected in all 9 establishments they were selected to be representative of all conditions encountered. Most of the foundries used a 130 mesh olivine with additions of 4 percent southern bentonite and 1 percent western bentonite. Figure 1 presents this air-borne particle-size distribution. Approximately 96 percent of all particles were 3 microns or less.

Dust Concentrations—Levels of dustiness in a foundry using olivine appears to be no different than any other foundry. Ranges of dust concentrations in million particle per cubic foot of air (mppcf) are shown below:

Molding: 3- 8 MPPCF
Shakeout: 7- 38 MPPCF
Conditioning: 10-106 MPPCF

These conditions represent foundries with good and poor dust control systems.

V. TOXICITY DATA, INDUSTRIAL EXPERIENCE AND THRESHOLD VALUES

Technical experiments in Norway on the use of crushed olivine rock have been carried out on a large scale since 1935 and accordingly the first reports on the health aspects of olivine originated there. Elstad and Stenvik[1] have carried out animal experiments in Norway beginning in 1940 to ascertain whether or not olivine dust might involve a silicosis hazard.

Rabbits were subjected to an air supply containing 20,000-40,000 particles per cm^3 of olivine dust (566 to 1,132 million particles per cubic foot of air) for 2-4 hours daily, foreign body reactions were observed after 508 days but without sign of silicosis. In a control group which inhaled the same quantity of silica dust, severe silicosis developed.

Corresponding experiments on guinea pigs and rabbits were carried out in the United States by Dr. Gardner[2] during the years 1944-1946. His unpublished report states: "you can conclude that Norwegian olivine is inert and incapable of causing pulmonary damage if inhaled. Collateral tests were made with American olivine. These likewise showed no suggestion of irritating properties.

Two surviving rabbits of this senes will ba allowed to live out their days in order to convince people that olivine is a harmless silicata."

In 1945 King. Goldschmidt and others[4,5,6] reoorted their results of affect of olivine dust on rats by intratracheal injection. Thasa findings state: "a study of the lasions producad by the reaction to olivine indicates a simple foreign body type response. There is no organization with raticulin fibrosis. The dust appears to be non-toxic in comparison with silica." Then in 1956 Nagelschmidt and King[7] furthar showed that olivine is non-hazardous to animal lungs whan given in the same quantities of silica.

During the years 1960-63 a numbar of investigations[1,8,9,10,11,12] were reported from the Scandinavian countries. These were tha concurrant afforts of all thosa intarested and concarned in tha haalth asoects of olivine. They involved comparativa pathologic pulmonary affects of pura olivine, quartz. farro-silicon. titanium dioxide and olivine from a steel foundry that had a free silica contant of 2-3.5 percant. Avaraga particla siza of dust was below 3 microns.

Quantities of 20, 40 and 80 mgs ware intratracheally injected in diffarent series during the pariod of obsarvation. All of tha animals injected with olivine and titanium dioxide aopeared to be unaffected and showed normal growth. Rats injected with quartz, on tha other hand became affected, lost weight and towards the and of tha pariod of observation died in considarable numbers.

For assessment of the pulmonary changes a scala was employed that denoted "a-e", "a" signifying minimal changes (normal findings) and "a" very advanced changes in tha entira lung. Tha results are shown in Tabla 4. and also includes tha rasults of the histological axamination utilizing a scale from 1 to 5. This is furthar illustrated in Figura 2.

Other data showing affects of differant amounts and types of dusts on weight of lungs and regional lymph nodas and collagan content ara shown in Figure 3.

Results of tha tasts involving olivina dust from a steel foundry shows tha gross pictura to be entirely similar to that found with pura olivine. Tha same applies to tha histological axamination, weight reaction of tha lungs and lymph nodes and collagan content.

In summary it was found that no kind of olivina dust gave risa to silicosis. Tha tissua raaction to olivina dust is a mera foreign body reaction typical of all dust introduced into the lungs. Tha raactions of olivine ara slightly diffarant than with an inart matarial such as titanium dioxida. but of a quita diffarant character to that produced by quartz which causes silicosis. Thus. all of thasa investigations reviewed have given claar evidence that olivine does not produca silicosis nor any other lung involvemant.

Tabla 1 refars to olivina as chrysolita. This should not be confused with chrysotila. The revarsal of tha lettars "l" and "t" can result in an inadvertant assessment of toxicity charactaristics.

The latter word. chrysotila. is an altaration reaction of asbestos and has been implicatad in othar lung involvements. This is not trua of tha matarial chrysolite.

Industrial Experience—Furthar information[1,13] from the Scandinavian countries reveal that during the past 19 years those in foundries using olivina as a mold material show no cases of silicosis among employees hired since the introduction of olivine. Former foundry employees. who had

developed silicosis when silica sand was used. are now allowed to transfar back to their original positions. It is felt the moderata lavels of olivina dust will not appreciably detariorate tha condition in a lung with moderate silicotic changes.

Also. no cases of silicosis or other types of pneumoconosis hava been reportad from tha olivina quarry during its 20 years of operation. Limited observation has not disclosed any detarioration in cases of silicosis when later axposed to olivine dust in modast concantrations.

Threshold Limit Values—Swedish health authorities[13,14] hava decided that foundries using olivine molding matarials shall be looked upon as "free from silicosis risk" allowing a maximum of 1800 particles par cm³ (50 million particles per cubic foot of air) with a maximum of 5 percent free silica in the olivina. Similar values prevail in Norway.

VI. DISCUSSION

An anvironmental study was undartaken in 9 non-ferrous foundries using olivina as a molding material to datermina its contribution to tha foundry working environmant.

In thase foundries tha frea silica contant of tha olivine molding aggregata and tha air-borna dust is considarably below that in foundrias using silica sand. No increase in free silica or tha modifications of tridymite or cristobalite ware present at tha olivina mold-matal intarfaca.

Tha use of silica cores is tha main sourca of silica contamination of olivine. Additives such as bantonite and other free silica bearing matarials no doubt add to this contamination. Olivine use in cores is rapidly gaining acceptance. To data there is no practical method of removing tha silica sand from tha olivine.

Tha free silica contant of the olivine molding aggregate in any given foundry will level off at a cartain value that is in relationship to tha amount of silica cores used. This valua appaars to ba maintained through carry-out and reduction of grain siza of tha silica and by the periodic additions of new olivine.

To data. axperienca in Scandinavian foundries indicates that when the free silica contant of olivine doas not axceed 5 parcent thera is no risk of silicosis.

Dust concentrations and particle-siza distribution of air-borne dust. in both types of foundries. is assantially in tha same order of magnituda. Tha naed of wall angineered and maintained dust axhaust systems. at tha major dust producing operations. is still required in all foundries.

Tha cited litarature on pathological affects damonstrates that olivina. of itself. will not produce silicosis. pneumoconosis or othar lung involvaments. The main rasponsa is ona of simpla foreign body reaction that carries no haalth impairment implications.

In all of these investigations the major componants of olivine—MgO. SiO_2 and Fa_2O_3 wera within less than one percent of the United States composition of olivine shown in Tabla 1.

VII. CONCLUSION

Olivina is not a panacea by any means. Whethar and when to use olivine depands on many factors. In making this decision it cannot be denied that one of the important factors is its real potential in reducing the risk of silicosis.

TABLE 1

TYPICAL AVERAGE CHEMICAL AND MINERALOGICAL COMPOSITION OF OLIVINE

CHEMICAL ANALYSIS		MINERALOGICAL ANALYSIS		OTHER PROPERTIES
MgO	49.4%	Olivine (chrysolite)	92-93%	Specific Gravity 3.3
SiO_2		(fosterite — 84%)		
(combined silica)	41.2%	(fayalite — 9%)		Hardness (Mons Scale) 6.5-7.0
(free silica)	1.0%	Enstatite	5%	
Fe_2O_3	7.1%	Serpentines	1-2%	
Al_2O_3, MnO, Cr_2O_3	1.6%	Chromite	1%	
CaO	0.2%			
Ignition Loss	0.3%			

TABLE 2

PERCENT BY WEIGHT OF FREE SILICA IN OLIVINE AGGREGATE AND AIR-BORNE DUST

PLANT	No. of SAMPLES	RANGE	MEDIAN	MEAN
A	13 6*	5-54 5-22	29 9	27 11
B	5 —	11-20 —	17 —	16 —
C	8 —	12-19 —	15 —	15 —
D	6 3*	7-18 4-16	9 5	13 6
E	25 9*	3-23 2-8	7 4	10 4
F	7 3*	4-12 2-5	10 3	6 3
G	5 —	4-12 —	9 —	8 —
H	8 3*	3-10 2-3	7 2	7 3
I	13 5*	2-8 2-5	6 3	5 3
NEW OLIVINE	14**	—	—	<1

*air-borne dust samples
**70 150 200 mesh and flour

TABLE 3

PERCENT BY WEIGHT OF FREE SILICA IN AIR-BORNE OLIVINE AND SILICA DUST

OLIVINE		SILICA SAND	
RANGE	MEAN	RANGE	MEAN
3-11	5	8-46	23

TABLE 4

MEAN VALUES FOR LUNGS AND LYMPH NODES OF EXPERIMENTAL ANIMALS AT VARIOUS PERIODS AFTER EXPOSURE TO DUST[1]

PERIOD OF OBSERVATION	GROSS ASSESSMENT OF LUNG			MICROSCOPIC ASSESSMENT OF LUNG		
	OLIVINE	TiO_2	QUARTZ	OLIVINE	QUARTZ	TiO_2
1 month	a	b	e	1.3	2	1
2 months	a-b	c	e	1.7	3	1
4 months	a-b	d-e	e	1.6	4	1
8 months	a-b	e	e	1.5	5	1

EXHIBIT 6.3

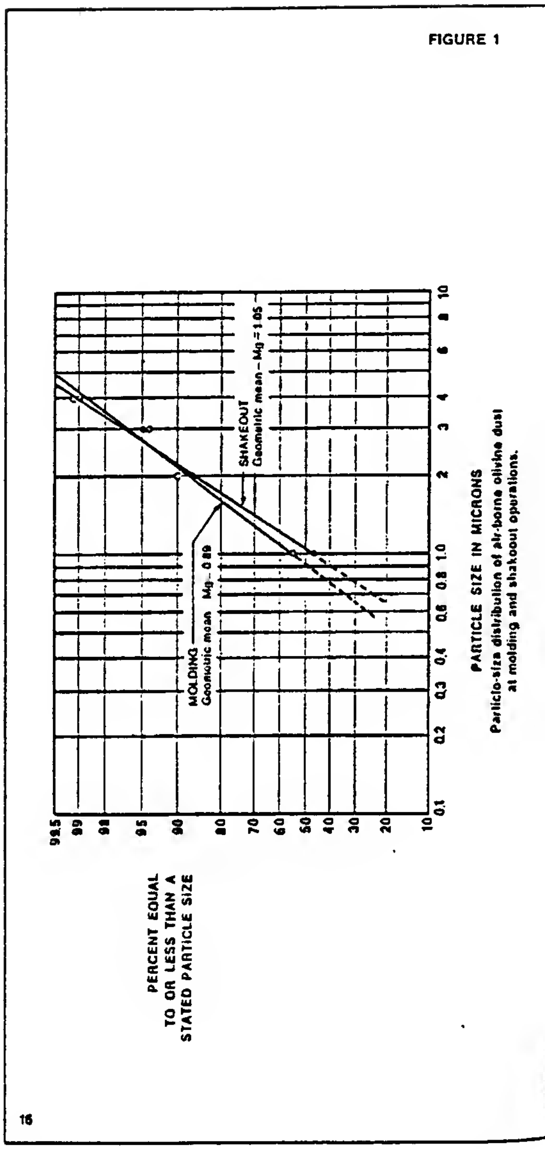


FIGURE 1
PERCENT EQUAL TO OR LESS THAN A STATED PARTICLE SIZE
MOLDING Geometric mean Mg - 0.89
SHAKEOUT Geometric mean - Mg = 1.05
PARTICLE SIZE IN MICRONS
Particle-size distribution of air-borne olivine dust at molding and shakeout operations.
16

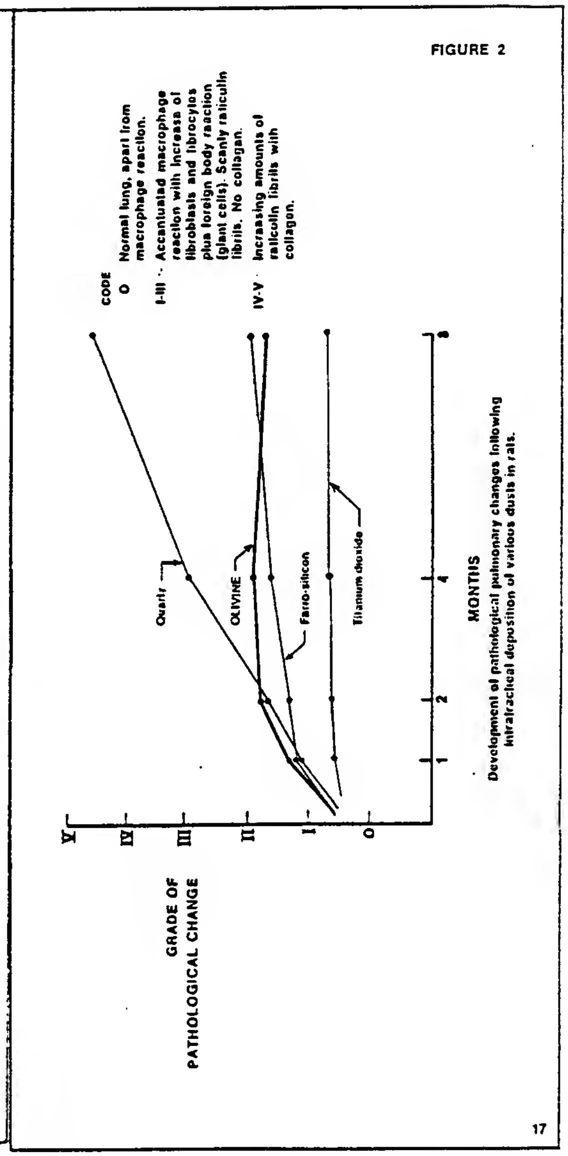
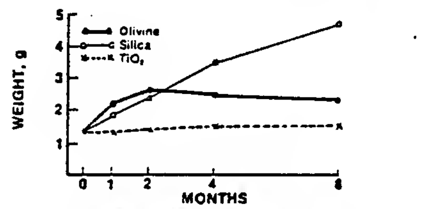


FIGURE 2
GRADE OF PATHOLOGICAL CHANGE
CODE
O Normal lung, apart from macrophage reaction.
I-III Accentuated macrophage reaction with increase of fibroblasts and fibrocytes plus foreign body reaction (giant cells). Scanty reticulin fibrils. No collagen.
IV-V Increasing amounts of reticulin fibrils with collagen.
Quartz
OLIVINE
Ferro-silicon
Titanium dioxide
MONTHS
Development of pathological pulmonary changes following intratracheal deposition of various dusts in rats.
17

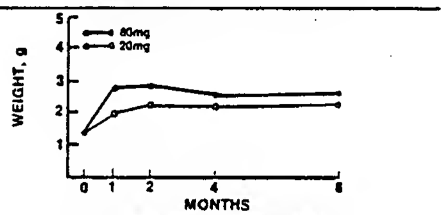
EXHIBIT 6.4

FIGURE 3

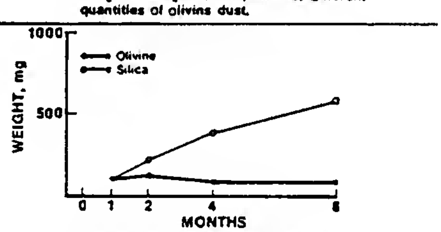
Average weight of lungs, regional lymph nodes and collagen content of rats after exposure to various dusts in suspension.[11]



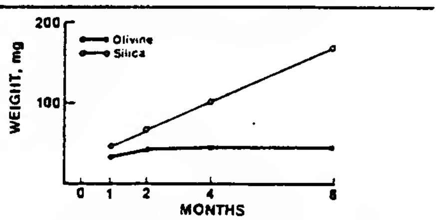
A. Weight of lungs after exposure to 40mg of different dusts



B. Weight of lungs after exposure to different quantities of olivine dust.



C. Weight of regional lymph nodes after exposure to 40mg of dust.



D. Content of collagen of lungs after exposure to 40mg of dust.

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EXHIBIT 6.5

Symptoms of pulmonary disorders are deceptive and include cough, dyspnea, wheezing, and repeated nonspecific illness in the chest. Pulmonary impairment is progressive. As is true of many pneumoconioses, the stages of progression depend on the duration of exposure and silica concentration. Upon inhalation and deposition in the lung, silica particles are attacked by macrophage (white blood cells) that attach themselves to the silica. Such an attack is part of the body's immune system and occurs with all foreign particles in the lung. Macrophage metabolize particles by producing enzymes that attack the particle. The process is called phagotosis. Research studies in vivo and in vitro suggest that the cytotoxic and fibrogenic activities of silica are due to the rupture of the macrophage lysosomal membrane and the release of a factor, (probably lytic enzymes) that produces cytoplasmic damage as it diffuses into the surrounding medium. Following lysis of the macrophages, the phagocytized free silica particles are liberated and can cause further damage to fresh macrophages. Further tissue changes, (i.e., perivascular aggregation of lymphoid tissue and fibrosis) may follow, but it is uncertain what chain of events leads from the damaged macrophage to fibrosis. The factor or factors released from the fresh silica damaged macrophage are believed to be responsible for stimulating collagen formation. After ingesting fresh silica particles, the macrophage degenerate and liberate certain toxic substances as well as the ingested particles. The ingested particles are again taken up by fresh macrophage to repeat the cycle. The toxic substances initiate the cellular reaction, which consists of new macrophage, mast cells, fibroblasts, and plasma cells. Phospholipids are also released from dying macrophage and cause stimulation of fibroblasts, which leads to collagen formation.

Although there is general agreement that deposited free silica particles are engulfed by phagocytic cells, that are rapidly destroyed, the fibrogenic effects are not yet fully understood. Why silica, with such a simple chemical composition and low chemical activity, has such a selective toxicity for one cell type (the macrophage) while other particles of comparable size and surface area (such as carbon or diamond dust) are ingested by cells without harmful effects is a vexing question and the subject of continuous study.

The common tests for diagnosing silicosis are a pulmonary function test, chest X-ray, and occupational history. The pulmonary function test measures only lung performance and cannot identify silicosis specifically. The chest X-ray is a moderately good indicator of the degree of tissue reaction to exposure to free silica. Unfortunately, several other diseases produce the same X-ray results as free silica. The X-ray can detect silica particles, but it cannot detect fibrogenic lesions. Thus dust particles of iron, tin, and barium can be detected, but they do not produce the lesions that silica produces. A lesion of silicosis is a firm nodule composed of concentrically arranged bundles of collagen (fibrosis scar tissue). These nodules are 1 to 10 mm in diameter and appear in lymphatics

around blood vessels and beneath the pleura in the lungs. The presence of one or more of these characteristic nodules in a lung indicates exposure to free silica. These nodules may also occur in the mediastinal lymph nodes. Nodular lesions in the silicotic lung may fuse; such fusion is called progressive massive fibrosis. The severity of silicosis is determined by the number and size of the silicotic nodules in the lungs. Frequently, the lumina of the blood vessels are narrowed and/or obliterated by fibrous tissue. An additional result is perifocal emphysema (i.e., destruction of alveolar walls with a concomitant increase in the size of the alveolar sacs and ducts, which decreases blood flow and lung ventilation).

Coalworker's pneumoconiosis (CWP) and silicosis produce different pulmonary lesions. The CWP lesion consists of a dense aggregate of coal dust around respiratory bronchioles and alveolar ducts. Varying amounts of collagen are present, and bundles of collagen are arranged haphazardly and not concentrically as in the silicotic nodule.

The toxicology of olivine has not been studied as exhaustively as silica, but there are sufficient data to support the contention that it does not produce the symptoms of silicosis. The body's reaction to olivine is similar to that which accompanies the inhalation of any other foreign agent. Exhibit 6 is a summary of health effects of olivine. Figures 2 and 3 in Exhibit 6 contrast the effects of olivine and free silica and support the claim that olivine does not produce silicosis.

One of the largest single factors causing uncertainty in statements concerning the toxicology of silica and olivine (or any other contaminant, for that matter) is the smoking habits of individuals. The relative safety of olivine over silica sand is a fact, but in application to specific foundries containing specific individuals with different smoking habits, it is very difficult to forecast improvement in the health of workers. Nonetheless, conclusions are drawn and strategies are chosen on the basis of the data above.

STUDENT STUDY QUESTIONS

1. Many terms in this section may be unfamiliar to engineers. Define the following terms. If you do not know the term, look it up and define it succinctly in a manner that conveys meaning to other engineers.

   (a) pulmonary fibrosis
   (b) pneumoconioses
   (c) macrophage
   (d) phagotosis
   (e) in vivo, in vitro
   (f) cytotoxic activity
   (g) toxicology

(h) lysis
(i) perivascular aggregation of lymphoid tissue
(j) cytoplasm
(k) collagen
(l) mast cells
(m) phospholipids
(n) fibrogenic lesions
(o) mediastinal lymph nodes
(p) alveoli
(q) bronchioles and alveolar ducts
(r) cilia

2. Explain why fibrosis nodules reduce physical stamina.

3. Contrast silicosis, coalworker's pneumoconiosis, asbestosis, and bissinosis.

4. Describe the deposition of dust in the pulmonary system as a function of particle size and breathing rate. See reference 10 for details.

5. Contrast the terms "respirable particles" and "inhalable particles."

6. Describe bronchitis, emphysema, and asthma.

Section 2 - Engineering Economics

The decision to use olivine sand or to install dust control equipment or some combination of the two required an analysis of the expense of each alternative. To compare costs rationally required that each alternative be cast in an equivalent way. An economic analysis was begun by Dr. John M. Samuels and finished by Professor Kenneth Knott, both members of the Department of Industrial Engineering at Penn State, as a portion of the SIR matching grant from Penn State to Roaring Spring Foundry. What follows is a summary of the model giving the results for a series of alternatives. The material will be presented so that the reader can use the model with different input data such as tax rates, capital costs, loan interest rates, cash flows, inflation rates, etc.

The installation of engineering controls involved additional yearly operating expenses and a significant initial investment that could be offset by reducing the company's tax liability through investment tax credits, interest payments, and major depreciation. On the other hand, the use of olivine required a smaller initial investment that was not eligible for depreciation or investment tax credit.

The economic analysis was based on a method called the net

present value (NPV) because it expressed money, costs, etc. in terms of their present values. The analysis was also relatively simple to formulate. The NPV method accounted for future cash flow (positive values for receipts and negative values for expenditures) by discounting them back to the present time to account for their present value. The sum of these present values yielded the NPV, since expenditures (cash outflow) associated with the investment were deducted from the revenues (cash inflows) generated by the investment.

When the number of castings produced increases each year, it is useful to define the scale factor (W,t):

$$W,t = (\text{output at a future time/present output}) - 1 \qquad (1)$$

To illustrate the scale factor, assume that the number of castings produced each year for a 5-year period is given by Table 2.

TABLE 2
ANTICIPATED PRODUCTION RATE

t(years)	No Castings	Change from t = 0	W,t
0	500	---	---
1	500	0	0
2	525	25	0.05
3	550	50	0.10
4	575	75	0.15
5	600	100	0.20

If 500 castings required $1,200 in cores at time zero (t = 0), core costs associated with increased production at a subsequent time would be:

$$\text{cost of cores in interval } (t) = \$1,200\ (1 + W,t) \qquad (2)$$

Because the economic futures of the company and the nation are difficult to predict, it would be helpful if economic forecasts contained limits of uncertainty. The NPV method incorporated mean (or expected) values and a variance. These two values afford managers the opportunity to use their personal preference for certainty and uncertainty in planning.

The model incorporated tax provisions of the 1978-79 federal tax code, in which engineering control systems could be depreciated if they satisfied the following conditions:

> A certified pollution control facility must be depreciable property that is a new identifiable treatment facility used for

> abating or controlling water or atmospheric pollution or contamination by removing, altering, disposing, storing, or preventing the creation or emission of pollutants, contaminants, wastes or heat and that is appropriately certified by the State and Federal certifying authorities. However, no certification may be made if it appears that the cost of a facility will be recovered from its operation (e.g., sales of recovered waste, etc.). A new identifiable treatment facility includes only tangible property subject to depreciation. It does not include a building and its structural components that is not exclusively a treatment facility. It includes only construction, reconstruction, or erection completed after 1968 or property acquired after 1968, if the original use of the acquired property began with you after that time and you place it in service before 1976.

Depreciation was calculated following the decision tree shown in Figure 5 when the lifetime exceeded 15 years. The model used a straight-line depreciation. Such a method was conservative and resulted in a prudent estimation of NPV. The model could be adjusted to include any other depreciation schedule. The model predicts an after-tax NPV, assuming the tax rate was constant. In addition to favored depreciation, a certified pollution-controlled facility was eligible for investment credit. The total investment credit for such facilities was 10% of their initial value, but the amount in any one year could not exceed the tax liability for that year. For simplicity, it was assumed that the total investment credit would be taken in the first year.

An amortization period of 5 years was assumed because management believed the political climate of the United States was so uncertain that one could not anticipate events beyond this period. The installation of dust control equipment required an initial investment, but the basic operations in casting metal remained the same. The substitution of olivine, on the other hand, required changing many operations and creating new ones so that disbursements changed substantially. The NPV method required the user to identify these additional incremental expenses for specific, identifiable operations--that is, additional expenditures or revenues for certain activities resulting from the substitution of olivine for silica sand.

Incremental cash flow items were grouped in two categories called alpha (a) and beta (b). Category alpha included items whose value was independent of the number of castings produced by the foundry in a year, whereas category beta items were dependent on the number of castings produced in a year.

$$\begin{aligned} &\text{Alpha } (a)\text{: independent of volume, } a = 1, 2, 3, \ldots, v \\ &\text{Beta } (b)\text{: dependent on volume, } b = 1, 2, 3, \ldots, r \end{aligned} \qquad (3)$$

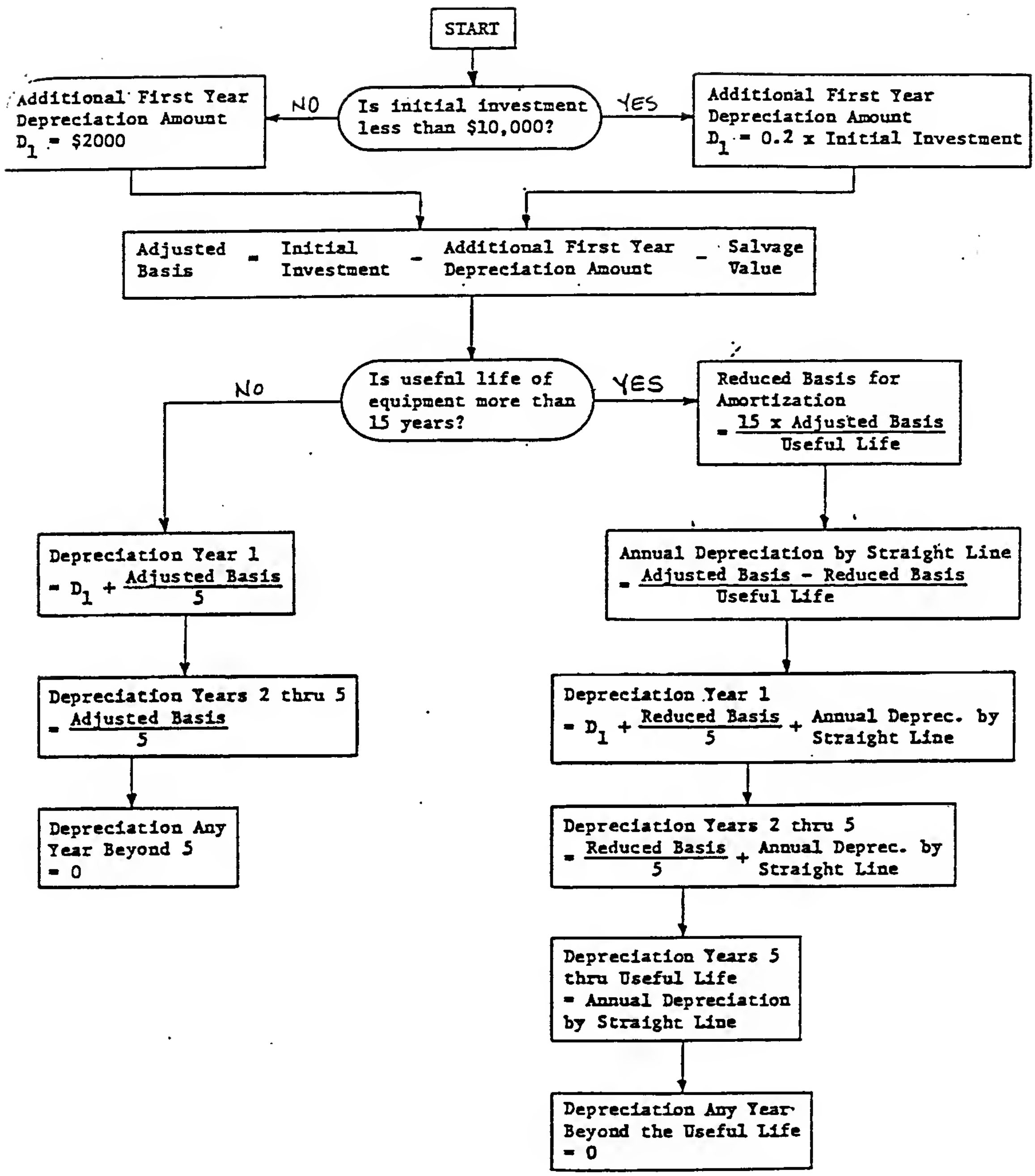

FIGURE 5. Decision model for depreciation and amortization of pollution control facilities.

(The comma preceeding a symbol is equivalent to using the symbol as a subscript). At a particular time, t (where t = 1, 2, 3, 4, 5), there might be an incremental cash flow from each of these sources. The variable F,ta represented the incremental cash flow from sources alpha at time t; and F,tb represented the incremental cash flow from source beta at time t.

A cash flow diagram over the 5-year period was constructed as shown in Figure 6. The net before-tax incremental cash flow for year (Y,t) was equal to

$$Y,t = \sum_{a=1}^{v} F,ta \quad + \quad \sum_{b=1}^{r} F,tb \tag{4}$$

The terms F,0a, and F,0b represented the incremental cash flow during the first year (t = 0) associated with a particular control strategy. It was assumed that they remained the same during subsequent years.

$$\begin{aligned} F,0a &= F,1a = F,2a = F,3a = F,4a = F,5a \\ F,0b &= F,1b = F,2b = F,3b = F,4b = F,5b \end{aligned} \tag{5}$$

The method can be changed to include differing amounts each year if the user wishes to do so. To reflect uncertain economic conditions in subsequent years, the incremental cash flow items were treated statistically by the beta distribution function where

F,0ap and F,0bp = pessimistic estimates of F,0a and F,0b

F,0am and F,0bm = most likely estimate of F,0a and F,0b

F,0ao and F,0bo = optimistic estimates of F,0a and F,0b

Assuming that F,0a and F,0b were independent, the expected value and variance in F,0a and F,0b were

$$\text{Expected value:} \quad E(F,0a) = (F,0ap + 4(F,0am) + F,0ao)/6 \tag{6}$$

$$\text{Variance:} \quad V(F,0a) = (F,0ao - F,0ap)\,(F,0ao - F,0ap)/36 \tag{7}$$

and similarly for E(F,0b) and V(F,0b).

In terms of the net before-tax incremental cash flow for year zero, the expected net before-tax increment, E(Y,0), and variance net before-tax increment, V(Y,0), were

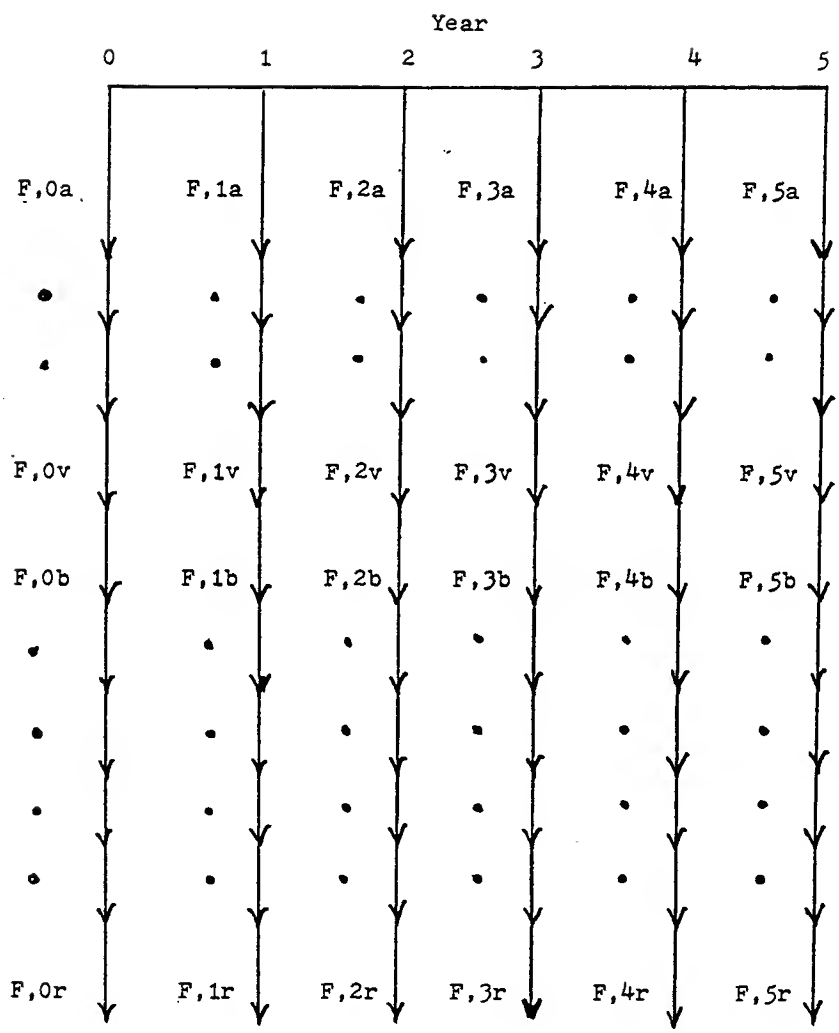

FIGURE 6. Cash flow per year.

$$E(Y,0) = \sum_{a=1}^{v} E(F,0a) + \sum_{b=1}^{r} E(F,0b) \quad (8)$$

$$V(Y,0) = \sum_{a=1}^{v} V(F,0a) + \sum_{b=1}^{r} V(F,0b) \quad (9)$$

Inflation was incorporated in the analysis by defining (g,a) and (g,b) as inflationary rates for cash flow items alpha (a) and beta (b). Thus in any year, t, the before-tax incremental cash flow was equal to

$$E(Y,t) = E(Y,0)\ (1 + g,a)\ **t \quad (10)$$

$$V(Y,t) = V(Y,0)\ (1 + g,a)\ **2t \quad (11)$$

where the mathematical operator ** denotes that the quantity is to be raised to a power (FORTRAN notation). Similar expressions were written for net cash flow items beta (b). Thus for any year, the net before-tax incremental cash flow had an expected value and variance of

$$E(Y,t) = \sum_{a=1}^{v} E(F,0a)\ (1 + g,a)**t + \sum_{b=1}^{r} E(F,0b)\ (1 + g,b)**t \quad (12)$$

$$V(Y,t) = \sum_{a=1}^{v} F(F,0a)\ (1 + g,a)**2t + \sum_{b=1}^{r} V(F,0b)\ (1 + g,b)**2t \quad (13)$$

Since the production rate of castings was not constant, the scale factor (W,t) defined earlier was incorporated in the variable volume net cash flow (items denoted by b). Items in category a were not affected. Thus the net before-tax incremental cash flow was

$$E(Y,t) = \sum_{a=1}^{v} E(F,0a)\ (1 + g,a)**t + (1 + W,t) \sum_{b=1}^{r} E(F,0b)\ (1 + g,b)**t \quad (14)$$

$$V(Y,t) = \sum_{a=1}^{v} V(F,0a)(1 + g,a)**2t + (1 + W,t)**2 \sum_{b=1}^{r} V(F,0b)(1 + g,b)**2t \quad (15)$$

Purchasing dust control equipment was assumed to require a loan of value (L) having an interest rate (I) paid yearly on the unpaid balance. Furthermore, it was assumed that the loan would be repaid in five equal yearly installments. thus the yearly interest payment in year t was

$$K,t = I\ (L - (t-1)\ L/S) \quad (16)$$

To determine taxes, depreciation, and investment credit, the following was defined:

P = total capital expenditure associated with the two methods that are being compared (the expenditure included the cost of equipment, construction, sand, and other major items).

PA = the portion of P for engineering dust control equipment

PO = the portion of P for olivine sand

Users of the economic model divided the above as they wished, depending on which two strategies they wished to contrast. The 1978-79 federal tax codes indicated that expenditures for dust control equipment (PA) were eligible to certain allowances that were not available for expenditures for the purchase of olivine (PO). The following was a summary of the federal tax code:

N = estimated useful life of the engineering dust control equipment.

I,t = tax rate on earned income.

S = salvage value of the dust control equipment.

D,1 = additional first-year depreciation.

$$D,1 = \begin{cases} (0.2)\ PA & \text{for } PA < \$10{,}000 \\ \$2{,}000 & \text{for } PA > \$10{,}000 \end{cases} \qquad (17)$$

The amortization basis (A,b) was

$$A,b = \begin{cases} (PA - D,1 - S)\ 15/N & \text{for } N > 15 \text{ years} \\ (PA - D,1 - S) & \text{for } N < 15 \text{ years} \end{cases} \qquad (18)$$

The straight line depreciation basis (B) was,

$$B = (PA - D,1 - S) - A,b \qquad (19)$$

For each year the depreciation was a constant and equal to

$$D,a = (A,b/5) + (B/N) \qquad (20)$$

If engineering controls were installed, the company's tax liability could be reduced by an investment Credit (I,c) for the first year (t=0).

$$I,c = (0.1)\ PA \qquad (21)$$

The expected after-tax cash flow was computed from

$$\text{Gross taxable income:} \quad G,t = E(Y,t) - K,t - D,a - D,1 \tag{22}$$

$$\text{Tax:} \quad TAX,t = (I,t)\ (G,t) - I,c \tag{23}$$

where t = 1, 2, 3, 4, 5 and D,1 = I,c = zero for t = 2, 3, 4, 5. The expected after-tax cash flow was equal to

$$E(X,t) = E(Y,t) - K,t - L/5 - TAX,t \tag{24}$$

Based on these after-tax cash flows, the expected NPV and its variance were:

$$E(NPV) = \sum_{t=1}^{5} E(X,t)\ (1 + i)^{**-t} + P \tag{25}$$

$$V(NPV) = \sum_{t=1}^{5} V(X,t)\ (1 + i)^{**-2t} \tag{26}$$

where V(X,t) = V(Y,t), and i was the desired after-tax rate of return on investment.

The economic model enabled the company to perform two types of analysis: It computed the difference between the equivalent costs of two different control strategies, and it provided a way for the company to investigate how sensitive these costs were to various economic parameters. Five alternative strategies for the Roaring Spring Foundry were subjected to the economic analysis. Table 3 shows the expected value and variance in NPV for these alternatives. Common to all five alternatives were the following:

Tax rate on earned income (I,t) = 0.48
Desired rate of return on investment = 0.02
Scale factors: W(1) = 0.0 W(2) = 0.05 W(3) = 0.10
W(4) = 0.15 W(5) = 0.20

The five alternatives corresponded to the following actions the company could take:

1 - No engineering controls but 100% conversion to olivine

2 - Total reliance on engineering controls and continued use of silica sand.

3 - Continued use of silica sand and installation of engineering controls in selected parts of the foundry.

4 & 5 - Different mixtures of engineering controls and olivine substitution at selected parts of the foundry.

Table 3 - Results Of Economic Analysis

ALT	F,Oao (k$)	F,Oap (k$)	F,Oam (k$)	g,a ($)	F,Obo (k$)	F,Obp (k$)	F,Obm (k$)	g,b ($)	L (k$)	I ($)	PA (k$)	PO (k$)	N (yrs)	S (k$)	ENPV (k$)	VNPV (k$)
1	- 0.9	- 1.1	- 1.025	5	- 9.0	-10.5	-9.9	7	--	--	--	--	--	--	---	---
	-10.0	-12.0	-10.75	6	- 0.8	- 1.0	-0.895	5	0	0	0	35.0	0	0	-110.3	1,257.7
	---	---	---	-	- 1.4	- 1.7	-1.625	6	--	--	--	--	--	--	---	---
2	- 0.9	- 1.1	- 1.025	5	- 9.0	-10.5	-9.9	7	--	--	--	--	--	--	---	---
	-10.0	-12.0	-10.75	6	---	---	---	-	--	--	--	--	--	--	---	---
	- 1.3	- 1.475	- 1.4	5	---	---	---	-	100	9.5	195	0	25	10.0	-138.1	1,242.6
	- 0.45	- 0.65	- 0.55	7	---	---	---	-	--	--	--	--	--	--	---	---
3	- 0.9	- 1.1	- 1.025	5	- 9.0	-10.5	-9.9	7	--	--	--	--	--	--	---	---
	-10.0	-12.0	-10.75	6	---	---	---	-	--	--	--	--	--	--	---	---
	- 1.3	- 1.475	- 1.4	5	---	---	---	-	0	0	135	0	5	23.5	-147.9	1,275.4
	- 0.45	- 0.65	- 0.55	7	---	---	---	-	--	--	--	--	--	--	---	---
4	- 0.9	- 1.1	- 1.025	5	- 9.0	-10.5	-9.9	7	--	--	--	--	--	--	---	---
	-10.0	-12.0	-10.75	6	- 0.8	- 1.0	-0.895	5	--	--	--	--	--	--	---	---
	- 1.3	- 1.475	- 1.4	5	- 1.4	- 1.7	-1.625	6	0	0	110	10.0	15	19.0	-151.1	1,270.2
	- 0.45	- 0.65	- 0.55	7	- 1.15	- 1.3	-1.2	7	--	--	--	--	--	--	---	---
5	- 0.9	- 1.1	- 1.025	5	- 9.0	-10.5	-9.9	7	--	--	--	--	--	--	---	---
	-10.0	-12.0	-10.75	6	- 0.8	- 1.0	-0.895	5	0	0	85	25.0	20	8.0	-296.9	1,242.6
	- 1.3	- 1.475	- 1.4	5	- 1.4	- 1.7	-1.625	6	--	--	--	--	--	--	---	---
	- 0.45	- 0.65	- 0.55	7	---	---	---	-	--	--	--	--	--	--	---	---

Table 3 indicates that the total conversion to olivine is about 20% cheaper than (100%) engineering controls, and considerably cheaper than combinations of controls and olivine. An amortization period of 5 years significantly biases the analysis in favor of non-capital-intensive alternatives and it is uncertain if the same conclusions could be drawn with an amortization period of 10 to 20 years. Secondly, since the variance associated with each NPV is nearly 10 times the NPV, the rankings in Table 3 must be taken with some reservation. Because the variance was so large, the parameters used in the analysis should be reviewed with an eye toward reducing the variance. Otherwise, users are apt to attribute significance to values of NPV that are not warranted.

The company chose to partially substitute olivine for silica sand and install some engineering controls. The choice produced initial improvements but they quickly faded as the olivine became contaminated with silica. Contamination was not anticipated, and even if it had been, the above model does not contain features to reflect such an occurrence. The economic model lacked the very factor that proved to be crucial! This fact should reinforce the suggestion made earlier that the cheapest method is merely a calculation and is not necessarily the best, since the model may lack important factors that have been ignored or cannot be quantified.

STUDENT STUDY QUESTIONS

The following questions require the repeated use of the equations developed in the economic model. The questions should be answered by using short computer programs written for personal computers or programmable calculators.

1. Roaring Spring Foundry found to its dismay the olivine became contaminated after several month's use. Repeat the analysis assuming the company purchases 100 tons of olivine at a most likely cost (t = 0) of $58/ton. Include this cost as a volume-dependent cash flow (category b), assume also that the optimistic and pessimistic values are 10% above and below $58/ton and that the inflation rate is 5%. Will alternative 1 remain attractive?

2. Roaring Spring Foundry is apprehensive that if olivine becomes attractive, other foundries in the United States will switch to it. Since the number of olivine suppliers is limited, the company is worried that the price may rise precipitously. Repeat the analysis assuming that the rate of inflation on this cash flow will be 15% and that the optimistic and pessimistic values are 25% above and below the value of $58/ton at t = 0.

3. Proponents of tax simplification and reform suggest that reducing tax breaks (e.g., first-year depreciation,

investment credits, special tax credits for air pollution control, etc.) while at the same time reducing the overall tax rate will benefit the country's economy. Assume that the following changes are to be enacted.

(a) all inflationary rates are 3% and interest rates are 8%.

(b) overall tax rate is 30%.

(c) D,1 = 0 and I,c = 0.

If all other factors in Table 3 remain the same, repeat the analysis. Does the overall ranking of alternatives remain the same?

4. The data in Table 3 are based on an increased volume of castings--that is W(t) > 0. Roaring Spring wishes to examine the consequences of a down-turn in business. Assume that all parameters in Table 3 remain the same but that each alternative is subject to the following scale factors:

W(1) = 0, W(2) = 0.10, W(3) = 0, W(4) =-0.05, W(5) =-0.10

Repeat the analysis. Will the ranking order of applicable alternatives be affected? What is the cheapest way to satisfy OSHA standards?

5. The results in Table 3 are affected significantly by the choice of a 5-year amortization period. Repeat the calculation for a 15-year period and determine whether the non-capital-intensive alternative remains the cheapest.

Section 3 - Air Quality Survey

Workers in the foundry were affected by a variety of airborne material. Free silica, carbon monoxide, and vapors from the binders in the molding sand and cores produced when the molten metal entered the mold traveled throughout the workplace. For workers in close proximity to molten metal, heat stress could be of serious importance. Since the company had been cited for violations of the free silica standards, olivine substitution was considered and the air survey they requested concerned only free silica. The substitution of olivine addressed only the free silica concentration and none of the other contaminants above. The installation of engineering controls at other parts of the foundry would address the other air contaminants.

Olivine is a complex mineral composed of magnesium and iron silicates, it contains less free silica than conventional foundry

molding sand. Table 4 summarizes properties of olivine and silica sand. For many years, olivine has been used in Scandinavia as a molding sand and animal investigations (8,9,11) indicate that it is less toxic than silica sand. Since the foundry had been cited for violations of only the free silica standard, carbon monoxide and vapors from the binders were ignored. Mr. Martin believed that substituting olivine for silica sand in several if not all locations of the foundry would reduce the atmospheric free silica concentration and satisfy OSHA standards. Four surveys of the air quality were conducted to test the hypothesis:

October 1976	- Preliminary air quality survey (2 weeks)
November 1976	- Olivine substituted for silica sand in the molding area
January 1977	- First air quality survey (2 weeks)
June 1977	- Part of coremaking switched to olivine
August 1977	- Second air quality survey (2 weeks)
November 1977	- Third air quality survey (2 weeks)

The sampling program was conducted by Dr. John W. Davis at Penn State through a cooperative research program with SIR. The purpose of this section is to present and evaluate results published by Davis et al. (2,3). The results of other sampling programs conducted at Roaring Springs before and after the Davis survey will also be discussed (11).

Maximum airborne concentrations of substances that nearly all workers may be exposed to without adverse affects on their health are called permissible exposure limits (PEL) by OSHA and threshold limit values (TLV) by the American Conference of Governmental and Industrial Hygienists (ACGIH). The two sets of standards are very similar, and the two acronyms are often (but incorrectly) used interchangeably. The ACGIH is a large and respected professional group of individuals working in the field of industrial hygiene who establish health standards, measurement techniques, and engineering design guidelines to insure the health of individuals in the workplace. The ACGIH meets regularly to review and update air standards. By and large, TLV standards are more conservative and more attuned to particular features of the workplace than PEL's. The standards of OSHA, on the other hand, are federal regulations and are established formally with care, deliberation, and legal due process. PEL's change less frequently than TLV's. Nonetheless, OSHA standards are backed by a body of law and enforced by a Federal agency. Noncompliance results in fines and possible imprisonment. The ACGIH is one of the principal professional organizations guiding OSHA in formulating PEL's, and in some cases OSHA has adopted ACGIH standards. In everyday parlance, most workers refer to air standards as TLV's. In the case of airborne particles in the foundry, the OSHA and ACGIH standards are the same. Figure 7 is a copy of the OSHA Standard on Mineral Dust taken from the OSHA General Industry Standards. Shown below is the portion that is germane to the Roaring Spring Foundry.

TABLE 4
Properties of Silica Sand and Olivine

Property / Test Date	Old System (Silica Sand)	New System (Olivine Sand)
Test Date	10-6-76	11-15-76
AFS GRAIN Fineness	86.0	57.0
AFS Clay (%)	14.8	8.2
Active Clay (%)	4.0	3.8
Combustables (%)	1.2	3.8
Moisture (%)	5.1	3.4
Green Permeability	120.0	140.0
Green Compression (psi)	17.8	10.6
Green Shear	3.0	2.9
Mold Hardness	82.0	82.0
Dry Compression (psi)	42.0	—
Dry Shear (psi)	6.1	3.2

	Physical			Chemical	
	Silica Sand	Olivine		Silica Sand	Olivine
Color	White	Green	SiO_2	99.82%	41.2%
Hardness (Moh)	6.2	6.7	MgO	0.031%	49.4%
Density (gm/cc)	2.7	3.3	Fe_2O_3	0.019%	7.1%
Thermal Expan. (cm/cm)	0.018	0.008	Al_2O_3	0.049%	1.8%
Melting Point (^{o}C)	1710	1871	Other	0.081%	0.5%
Grain Shape	Round	Angular	Free Silica	~80%	~1.0%

TABLE Z-3—MINERAL DUSTS

Substance	Mppcf [a]	Mg/M³
Silica:		
Crystalline:		
Quartz (respirable)	$\frac{250 [f]}{\%SiO_2+5}$	$\frac{10mg/M^3 [m]}{\%SiO_2+2}$
Quartz (total dust)		$\frac{30mg/M^3}{\%SiO_2+2}$
Cristobalite: Use ½ the value calculated from the count or mass formulae for quartz.		
Tridymite: Use ½ the value calculated from the formulae for quartz		
Amorphous, including natural diatomaceous earth	20	$\frac{80mg/M^3}{\%SiO_2}$
Silicates (less than 1% crystalline silica) [a]		
Mica	20	
Soapstone	20	
Talc (non-asbestos form)	20 [e]	
Talc (fibrous). Use asbestos limit		
Tremolite (see talc, fibrous)		
Portland cement	50	
Graphite (natural)	15	
Coal dust (respirable fraction less than 5% SiO_2)		2.4mg/M³ or
For more than 5% SiO_2		$\frac{10mg/M^3}{\%SiO_2+2}$
Inert or Nuisance Dust:		
Respirable fraction	15	5mg/M³
Total dust	50	15mg/M³

NOTE: Conversion factors—
mppcf×35.3 = million particles per cubic meter
= particles per c.c.

[a] Millions of particles per cubic foot of air, based on impinger samples counted by light-field technics.

[f] The percentage of crystalline silica in the formula is the amount determined from air-borne samples, except in those instances in which other methods have been shown to be applicable.

[l] As determined by the membrane filter method at 430× phase contrast magnification.

[m] Both concentration and percent quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:

[e] Containing < 1% quartz; if > 1% quartz, use quartz limit.

Aerodynamic diameter (unit density sphere)	Percent passing selector
2	90
2.5	75
3.5	50
5.0	25
10	0

The measurements under this note refer to the use o an AEC instrument.[f] the respirable fraction of coal dust is determined with a MRE the figure corresponding to that of 2.4 Mg/M³ in the table for coal dust is 4.5 Mg/M³.

[39 FR 23502, June 27, 1974. Redesignated and amended at 40 FR 23073, May 28, 1975]

Figure 7. OSHA mineral dust standard.

Mineral Dust:

Silica, SIO2 (Quartz) (mg/cubic meter)
Respirable dust = (10 mg/cubic meter)/(% respirable quartz + 2)
Total dust = (30 mg/cubic meters)/(% quartz + 2)

Nuisance Particulate:

15 mg/m3 of total dust < 1 % quartz

The phrase "respirable dust" is important, and it is easily misunderstood. The definition undergoes continual refinement (see reference 10 for a systematic review of the definition and the instruments used to measure the respirable dust concentration). Between 1973 and 1979, the AEC defined respirable dust as that portion of the inhaled dust which penetrates to the non-ciliated portions of the lung. For practical purposes respirable particles were those having aerodynamic diameters (unit density spheres) of 2 micrometers or less. Air sampling instruments available at the time were designed with elutriators of various designs to remove nonrespirable particles from the sampled air.

Air samples were obtained by personal samplers, a cascade impactor, and a tape sampler. Individuals working in the above locations in the foundry wore personal samplers. Personal samplers were placed outside the positive pressure helmets of workers in the grinding area. The pump hung from their belts. The flow indicator was checked at the beginning, at the end, and at random times during the work day. The other instruments were positioned at designated locations within the foundry. Shakeout was done each afternoon and evening. For reasons beyond the control of those conducting the air survey, the windows and doors were kept open for ventilation during the first week of sampling in October 1976 and the 2-week period in August 1977. During the second week in October and the 2-weeks in January, all the doors and windows were closed. On Monday and Tuesday of the second week in January, salamanders (space heaters burning oil and used in the construction industry) were used to supply additional heat to the building. The production rates of castings during the sampling periods were similar except for August, when it was lower. These conditions typify operations in the foundry.

A tape sampler is a device that draws a sample of air through a filter (constructed in the form of a tape) at a controlled rate for a predetermined amount of time. Following this, the tape is advanced and a new sample is obtained. After the tests are completed, a light beam of light of known intensity and frequency is passed through the darkened area of the tape and the attenuated light is related to an overall dust concentration by means of a previously obtained calibration curve. Data from tape samplers are crude, but many samples can be taken easily and quickly over long periods of time to enable users to confirm measurements obtained from other instruments.

Five tape samplers were located at stations 1, 2, 5, 7, and 8 in the foundry.

Exhibit 7 is a schematic diagram of a six-stage cascade impactor used in the air quality survey. As the air travels down through the impactor, particles whose aerodynamic diameters fall between predetermined limits (i.e., $D_{p,1} < D_p < D_{p,2}$) are collected in each stage. An absolute filter is placed after the last stage to collect the smallest particles. The air volumetric flow rate is carefully controlled. After a sufficient sample has been obtained, the mass of particles in each stage is determined. The overall dust concentration can be computed as well as the distribution of particle sizes based on mass. Figure 8 is a typical normalized differential plot of the particle sizes in the grinding room. The graph indicates that the upper particle size is 30 to 40 micrometers in diameter. There is indication of a second mode within the respirable size range, but without error bars on the data, one cannot be sure.

Exhibit 8 is a schematic diagram of the personal sampler used in the study. Air is drawn through a small cyclone separator at 1.7 liters/minute, and all particles above an aerodynamic diameter of 2 micrometers are removed. The cut-off diameter of 2 micrometers is termed the "cut diameter." The air containing the respirable particles then passes through a filter where all the remaining particles are removed. The air is drawn through the system by a battery-powered pump that hangs from the worker's belt. Sampling times of 7 hours were used in the study. The cyclone and filter are contained in a device attached to the worker's lapel. Knowing the total volume of air drawn through the filter and measuring the mass of particulate matter contained on the filter after properly drying it before and after the test allows the user to calculate the average concentration of respirable dust in the worker's breathing zone during the sampling period. From the theory of cyclones, one can postulate that to a first approximation, the cut-size at volumetric flow rates other than the prescribed value can be estimated from

$$D_{P,50}\ (\text{actual}) = D_{P,50}\ (\text{ref}) \left(\left(\frac{Q(\text{ref})}{Q(\text{actual})} \right) \right)^{1/2} \qquad (27)$$

To measure the total dust concentration in the worker's breathing zone and to verify similar measurements made by other instruments, the cyclone was removed, and air was drawn directly through the filter at 2.0 liters/minute.

The accepted technique for measuring the silica content in the respirable particles was the Bumstead method (1). The essential steps in the method included incinerating the personal sampler filter, rinsing the residue and adding a known amount of calcium flouride (CaF_2) to the sample, transferring the entire residue to a 0.45-micrometer-pore-size silver membrane filter, and transferring the

THE ANDERSON SAMPLER
(2000 Inc.)

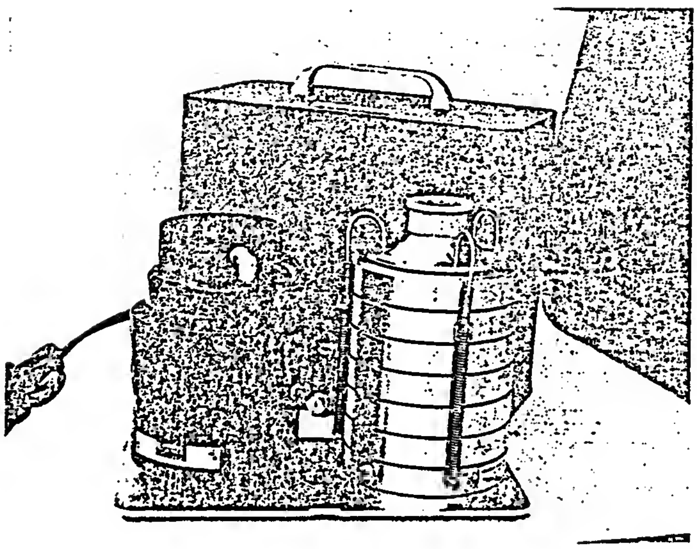

Fig. O-27. Anderson Sampler, including 1 cfm vacuum pump and carrying case.

DESCRIPTION

The Andersen Sampler is a multistage, multi-jet cascade impactor, used for the collection and sizing of airborne particles. There are two models, one for bacterial particles and one for other airborne particles. These instruments collect particles in aerodynamically graded sizes for determining size distribution and concentration. Since penetration and deposition of airborne particles in the respiratory tract depends on the aerodynamic dimension of the particles these samplers are used to indicate the health hazard with respect to lung penetration of any sample collected.

Air is drawn through the sampler (see Fig. O-28), producing a jet of air from each of the 400 holes in each stage, directed at the collection plate below. The size of the holes is constant for each stage, but is smaller in each successive stage. Consequently, the jet velocity is uniform in each stage, but increases in each succeeding stage. When the velocity imparted to a particle is sufficiently great, its inertia will overcome the aerodynamic drag and the particle will impact on the surface. Thus, each stage collects smaller particles than the preceeding one.

The low jet velocities, required in this device compared with other impactors (one third or less), minimize the blowing off or reintrainment of impacted particles. This eliminates the need, in some cases, of coating the plates with a sticky film and sampling is not limited to a monolayer in the impaction area.

PHYSICAL DESCRIPTION

Figure O-27 shows the Andersen Sampler complete with vacuum pump. It has six impaction stages, samples one cubic foot of air per minute, and weighs 12 pounds. In the bacterial model, the collection plate is a nutrient agar plate which permits culture of the collected particles, wherein those particles containing viable bacteria grow into visible colonies. In the model on the right, the airborne particles are collected on stainless steel or glass plates for microscopic study, or chemical, physical or radiological analyses. Figure O-28 is a schematic drawing of the bacterial model. The jet dimensions indicated on Figure O-28 apply to both models. The spacing between the plate with the 400 holes and the collection surface is 2-1/2 mm for all stages.

EXHIBIT 7
ANDERSON CASCADE SAMPLER

By permission of the American Conference of Governmental and Industrial Hygienists, Box 1937, Cincinnati, Ohio 45211.

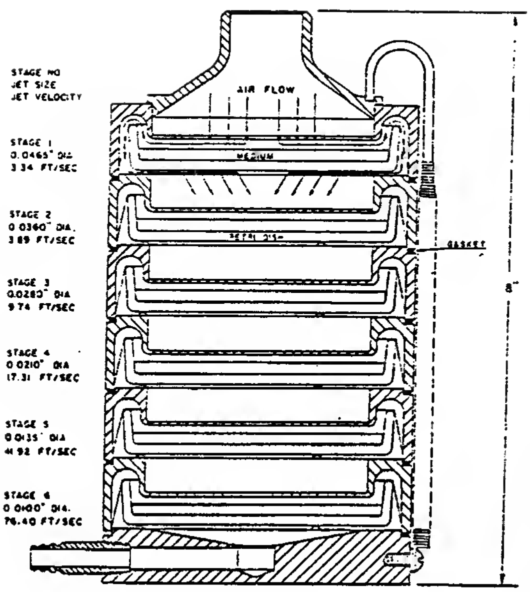

Fig. O-28. Cross-section of Andersen Sampler—Bacterial Model.

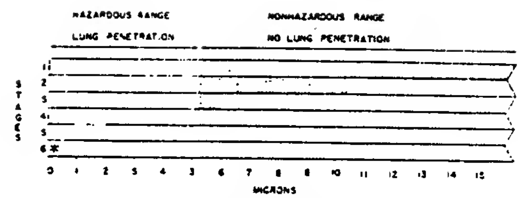

Fig. O-29. Relationship of Stage Distribution to Particle Size for Smooth Spherical Particles of Unit Density Collected in the Andersen Sampler. Each bar includes 95% or more of the particles collected on that stage.

Both samplers are die cast of corrosion resistant aluminum alloy with fasteners and outlets made of stainless steel. The stages are pressure sealed together with neoprene O-rings and three adjustable spring fasteners.

PERFORMANCE DATA

The sampler has been calibrated with respect to the size of standard spherical particles of unit density collected on each stage. Particles of unknown densities and shapes have the same aerodynamic dimension or lung penetrability as the standard spherical particles of unit density which are collected on the same stage. Lung penetrability of the standard particles is known; therefore, the stage distribution of any collected sample indicates the degree of respiratory tract penetration that would occur in exposed people.

Figure O-29 shows the size range of standard spherical particles of unit density collected on each stage of the sampler. This calibration has been confirmed by Dr. K. R. May. Work with the fine aerosols of some of the smallest bacteria has demonstrated that wall loss is extremely low and that there is no slippage in the bacterial sampler. Since there is no violent impinger action or dessication, as in other bacterial aerosol samplers the Andersen Sampler is extremely sensitive and efficient.

SOURCE

2000 Inc., 5899 South State Street, Salt Lake City, Utah 84017.

REFERENCES

Anderson, A.A.: A New Sampler for the Collection, Sizing and Enumeration of Viable Airborne Bacteria, JOURNAL OF BACTERIOLOGY 76:471 (November 1958).

Anderson, A. A.: A Sampler for Respiratory Health Hazard Assessment., Amer. Ind. Hyg. Assoc. J. 27:160 (Mar-Apr. 1966).

EDITORIAL NOTE:

Two other versions of the Anderson multi-stage multi-jet sampler are also available. One is the Mini-Sampler, whose description follows. The other is the Stack Sampler, which is described in Section L.

EXHIBIT 7.1
ANDERSON CASCADE SAMPLER

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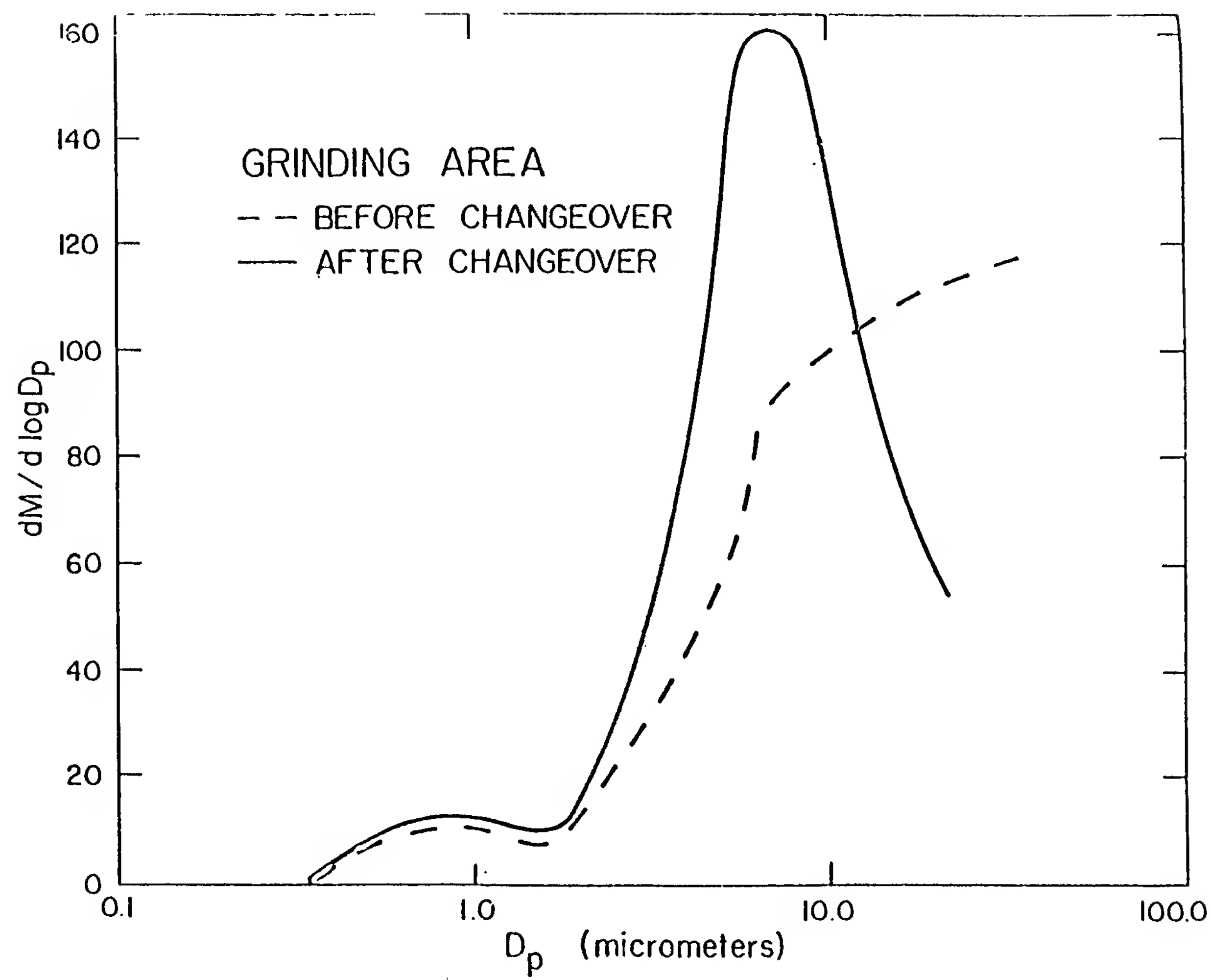


FIGURE 8. Noniodized plot of particle size distribution in grinding room.

EXHIBIT 8

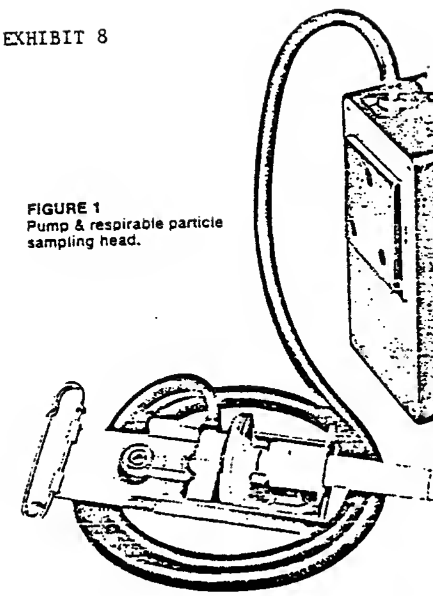


FIGURE 1
Pump & respirable particle sampling head.

Reliable Accurate Control

RAC

BULLETIN 2392-A

PERSONAL SAMPLER

designed to NIOSH & BuMines specifications, this minisampler collects respirable particles in any type of environment . . . is adaptable to sample ambient gases

• features

- Suitable for underground, indoor & outdoor air sampling applications
- Collects air pollution samples from the individual user's inhalation zone
- Particulates in 5 microns & smaller range are collected on preweighed membrane filter element
- Rechargeable batteries provide up to 16 hours of continuous operation
- Adjustable flow rates up to 3.0 liters per minute
- Battery charger has both overnight & slow charging rates
- Lightweight, sturdy, corrosion-resistant construction

• application

The RAC Personal Sampler meets all relevant performance and design specifications established by the National Institute of Occupational Safety & Health (NIOSH) and the U. S. Bureau of Mines (BuMines). It can be used in any type of environment to collect accurate samples of airborne particulates or gases that the user encounters during the exposure period. All gravimetric dust or gas samples are collected in the individual wearer's inhalation zone instead of just from the general environment, which is the situation with stationary sampling devices.

This minisampler can operate continuously for periods up to 16 hours when the batteries are fully charged. For optimum service life, however, the batteries normally should be recharged after every 8 hours of use. The system provides adjustable flow (air sample intake) rates up to 3.0 liters per minute (lpm). In addition, the pump assembly meets BuMines specifications for intrinsically safe operation, permitting its use where flammable or explosive atmospheres are a potential hazard.

The complete RAC Personal Sampler kit includes a sample-collecting head (3-piece cyclone), membrane filter casettes, portable pump, flexible tubing, battery charger, and complete operating/servicing instructions. The pump assembly contains a diaphragm-type vacuum pump, high-rpm dc motor, flow control valve, flowmeter, Ni-Cad battery pack and push-on/push-off switch.

Pump and sampling head are coupled by a flexible tubing that provides resistance to accidental disconnection.

When worn in mines, the sampling head uses a preweighed, encapsulated, membrane filter casette made to NIOSH standards. *All particles in the respirable range—5 microns (μ) and smaller—are collected on the preweighed membrane;* those larger in size fall into a removable grit cap at the bottom of the cyclone.

Ambient gases can be sampled by substituting appropriate gas indicator tubes or other collection devices for the sampling head assembly.

• operation

After the integral batteries are fully charged—using either a 16-hour (overnight) or a slow 64-hour (2.66 days) rate—the pump assembly is checked for operation, and then connected to the sampling head by flexible tubing. The desired air sample flow rate, which is indicated on the unit's flowmeter, is adjusted with a screwdriver.

Using a spring clip on the pump housing's removable side panel, the pump is attached to the wearer's belt, and the sampling head is pinned to the clothing near the shoulder. User then activates the pump and goes through a normal work routine or other exposure cycle.

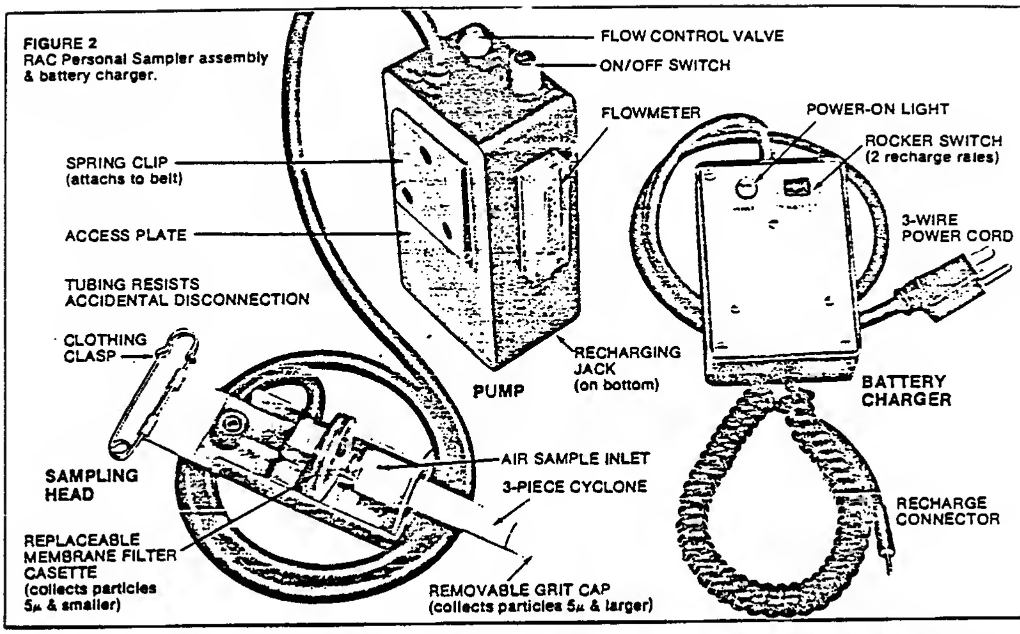
When exposure cycle is completed, the membrane filter element (or other sampling device) is removed and replaced with a clean unit for the next sampling cycle. Collected samples can be evaluated by the appropriate methods.

The battery charger's two rates are selected by a rocker switch. The 16-hour rate will fully recharge the batteries

EXHIBIT 8
RESPIRABLE PARTICLE SAMPLER

(reproduced from Research Appliance Company Bulletin 2392-A)

FIGURE 2
RAC Personal Sampler assembly & battery charger.



overnight. If desired, the pump unit can be connected indefinitely at the 64-hour rate. The batteries will not be damaged if accidentally left on charge longer than the stipulated time periods. A neon lamp indicates when the charger is operating.

When not in use, the RAC Personal Sampler should be stored in a clean, dry place. This sturdy, dependable mini-sampler will operate with optimum efficiency and minimal servicing/maintenance requirements if not subjected to accidental damage or abuse.

• specifications

Flow Rate
Up to 3.0 liters per minute

Operating Cycle
Continuous for up to 16 hours with fully-charged batteries

Power
PUMP ASSEMBLY: rechargeable nickel-cadmium batteries (3.6 volts dc)
RECHARGER: 115 volts, 60 Hz

Recharging Rates
16 hours (overnight) or 64 hours (slow/continuous charging)

Dimensions
PUMP: 3.125"W x 6"H x 2.25"D
SAMPLING HEAD: 8.25"L x 1.5625"W x 1.75"D

Weight
PUMP: 21 ounces
SAMPLING HEAD: 3.5 ounces

• ordering information

Specify by full name and catalog number. RAC Personal Sampler Kit, CAT. #2392-K. Complete kit includes pump, sampling head assembly, 10 membrane filter casettes, tubing, battery charger, and complete instructions packaged in a sturdy attache case. Catalog numbers and prices for individual components are furnished on separate sheets.

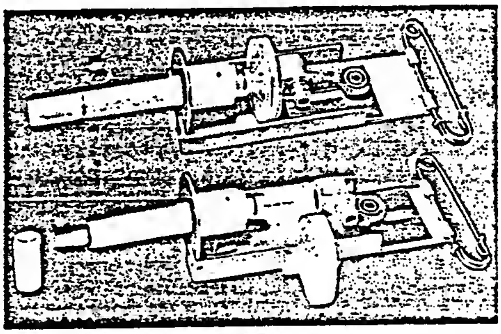


FIGURE 3
Gravimetric particle sampling head features easy disassembly for filter replacement & cleaning. Cyclone's top member (with O-ring seal) and its threaded grit cap are easily removed for cleaning whenever necessary.

• other sampling equipment

Research Appliance Company manufactures and supplies a wide range of precision instruments and systems designed for sampling/monitoring environmental air, water, and noise pollution. Write for descriptive literature, indicating the type(s) of products on which information is desired.

RESEARCH APPLIANCE COMPANY
Route 8, Gibsonia, Pennsylvania 15044
Environmental Instruments / Laboratory Products

Printed in U.S.A. 6/75

AIRBORNE INDUSTRIAL DUST

...an old sampling problem

Measurement of airborne dust has long been a concern in industry, particularly as regards the development of various techniques and instruments to distinguish between the smaller size dust particles which actually penetrate to the lung, and the larger, relatively less harmful particles which do not.

In an effort to help find a solution, the United States Bureau of Mines, and the United States Public Health Service are currently conducting a number of tests to determine an optimum sampling technique and type of sampling equipment. This brochure is intended to acquaint the reeder with one of these methods — gravimetric sampling — a technique which offers not only a new, more practical approach to the problem, but is also helping set new standards for airborne dust control.

...a new approach

A first step in the control of airborne dust is the determination of criterie of those dust sizes of hygienic importance. Because there is little understanding of the physiological mechanism associated with dust clearance in the lung, this criteria is the generally accepted deposition curve for dust in the terminal eirweys of the lung. One such size criterion has been defined by work performed by the United States Atomic Energy Commission, and its relationship to the generally accepted deposition curve is shown in the following.

United States Atomic Energy Commission (Los Alamos) Criterion

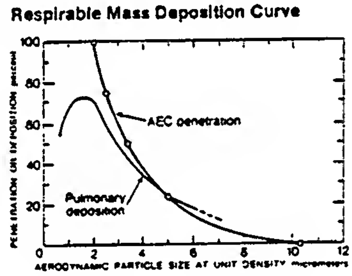
This criterion is defined by a sampling efficiency curve dependent on the aerodynamic behavior of the particles passing through the following points:

100% efficiency at 2 microns and smaller.

50% efficiency at 3.5 microns, and

0% efficiency for particles 10 microns and larger; all sizes referring to equivalent diameters.*

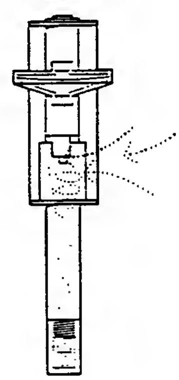
Respirable Mass Deposition Curve



...and a new sampling technique

Once the size criteria is determined, the next step in the control of airborne perticuletes is one of collection and measurement. Historically such collection and measurement has been based on the light-field microscopic count technique which provides a measurement of *all* of the airborne dust in a specific aree over a specified period of time. However, all airborne dust is not respirable, and as such never reaches the lungs. Only the smaller particles, usually below 5-micron size, reach the lower lung where they remain and build up over months and even years. These smaller particles, called the *respirable* fraction of airborne particulates, are the ones of hygienic significance; the larger particles, are usually considered non-respirable.

Because light-field microscopy of particulates fails to distinguish between respirable and non-respirable airborne dust, it has been of limited value in detecting and measuring the respirable fraction. What was needed was a technique — and instrument — that could simulete the lung in its selectivity of the respirable fraction of airborne dust. The gravimetric (weight) method of sampling provides that technique — Mine Safety Appliances Company provides the instrument.



M-S-A Gravimetric Dust Sampler... a rugged, compact monitor designed to meet the new concept in measuring airborne dust; and to meet the requirements of the Federal Coal Mine Health and Safety Act of 1969

MSA's Gravimetric Dust Sampling Kit consists of three basic components: (1) a battery-powered, diaphragm-type pump with three pre-calibrated flow rates; (2) a dual-rate battery charger; and (3) a cyclone assembly and a pre-weighed cassette or Filter Holder designed for personal monitoring.

In operation the Sampler is quite simple: the pump draws dust-laden air through the cyclone assembly and filter at a pre-selected flow rate. The cyclone stage of the assembly discards the larger non-respirable (above 10 micron) size particles. The smaller particles are trapped by a pre-weighed filter cassette or by a filter which was pre-weighed on a sensitive balance prior to sampling. At the end of the appropriate sampling period the total weight of dust is established on the filter medium and the dust concentration per cubic meter of air is determined.

Features

- Small, compact, lightweight, rugged construction
- Pump pre-calibrated for three flow rates: 2.0 lpm, 1.8 lpm and 1.6 lpm
- Minimum eight-hour continuous sampling
- Overnight battery charging
- Easy operation
- Cyclone assembly and filters designed for leak-proof operation
- Available as a complete kit with all accessories in attractive carrying case — nothing else needed
- Sampling pump has Bureau of Mines approval No. 2G-2239, and Environmental Health Service Bureau of Occupational Safety and Health Approval No. 1A-101.

sample to a glass slide to be placed in an X-ray diffractometer. Measurements were obtained at the alpha quartz primary peak (26.6 angstroms) and the primary peak of calcium flouride (CaF2) (28.3 angstroms). By taking the ratio of the peak heights of quartz to flouride and using a calibration curve for quartz, the micrograms of quartz in the original sample could be computed. The calibration curve was obtained by preparing standard mixtures of 5-micrometer quartz particles and flouride, subjecting them to X-ray diffraction, and obtaining the ratio of the peak heights.

Free silica is any S102 occurring in its pure form and not bound in compounds such as silicates. It is always crystalline, at least on the microscopic scale. The most common is called alpha-quartz, although cristobalite and tridymite are also found at times in industrial settings. Other types of crystals are rare and can be ignored.

Four categories of dust concentration were measured:

(1) Total dust - all particles obtained with personal samplers without their cyclones.

(2) Respirable dust concentration - personal samplers that capture particles of 2 micrometers or less.

(3) Respirable free silica concentration - fraction of respirable particles containing free silica.

(4) Suspended particles - particles of 10 micrometers or less measured by cascade impactor.

The data were grouped as follows:

Before changeover - October 1976

After changeover - January, August, and November 1977

Average concentrations for five areas of the foundry are shown in Table 5. The station breakdown is as follows:

Grinding	Stations 1,2
Main Floor	Stations 3,4,5,7
No-Bake	Stations 6,8
Main Floor Shakeout	Stations 3,4,5,7 (3-9 PM)
Core Shop	Stations 9,10

The average opacity measured at five locations for the four survey periods are presented in Table 6 and Figure 9. Table 7 summarizes data obtained with personal samplers in terms of the number of times the concentrations failed to satisfy OSHA standards. To the far left are the results of an OSHA inspection in 1973.

Table 5

Total Dust by Area Using the Cascade Impactor (mg/m^3)

		Grinding	Main Floor	No Bake	Shakeout	Core Shop
Before Changeover	$\bar{x}$	7.53	2.32	1.50	3.21	0.78
	s	6.99	1.30	0.73	1.29	0.71
	n	6	5	6	3	4
After Changeover	$\bar{x}$	3.42	3.31	2.56	2.38	0.77
	s	2.89	1.91	1.85	2.39	0.31
	n	10	16	10	9	7

Respirable Dust by Area Using the Cascade Impactor (mg/m^3) $d \leq 2.3$ μm

		Grinding	Main Floor	No Bake	Shakeout	Core Shop
Before Changeover	$\bar{x}$	0.47	0.44	0.30	0.54	0.15
	s	0.34	0.33	0.24	0.30	0.12
	n	6	5	6	3	4
After Changeover	$\bar{x}$	0.27	0.42	0.50	0.25	0.10
	s	0.29	0.24	0.66	0.12	0.07
	n	10	16	10	9	7

Respirable Dust by Area Using the Personnel Sampler (mg/m^3)

		Grinding	Main Floor	No Bake	Shakeout	Core Shop
Before Changeover	$\bar{x}$	1.6	0.73	1.16	0.89	0.33
	s	2.08	0.35	0.94	0.82	0.18
	n	1	10	8	7	2
After Changeover	$\bar{x}$	1.86	0.60	0.77	0.49	0.48
	s	1.22	0.31	0.94	0.26	0.21
	n	15	24	11	10	6

Suspended Dust by Area Using the Cascade Impactor (mg/m^3) $d \leq 10$ μm

		Grinding	Main Floor	No Bake	Shakeout	Core Shop
Before Changeover	$\bar{x}$	3.71	1.68	1.05	2.13	0.59
	s	2.25	1.03	0.58	1.15	0.53
	n	6	5	6	3	4
After Changeover	$\bar{x}$	2.51	2.09	1.97	1.28	0.52
	s	2.4	0.96	1.65	0.87	0.23
	n	10	16	19	8	7

Respirable Free Silica by Area Using the Personnel Sampler and X-ray Diffraction ($\mu g/m^3$)

		Grinding	Main Floor	No Bake	Shakeout	Core Shop
Before Changeover	$\bar{x}$	74.8	41.6	88.4	41.14	35.0
	s	78.7	27.5	79.4	24.6	18.4
	n	11	10	8	7	2
After Changeover	$\bar{x}$	55.9	29.9	34.4	18.2	34.8
	s	54.9	19.5	28.8	18.8	38.2
	n	13	24	10	10	6

Table 6

Tape Sampler Results (% Opacity)†

	Station No.		5AM - 3PM	3PM - 9PM	5AM - 9PM	9PM - 5AM	Overall Ave.
Portable Grinding	1	Before Changeover	35.0	38.8	36.4	8.2	27.0
		After Changeover	29.4	26.0	28.1	6.5	20.9
Stationary Grinding	2	Before Changeover	24.7	27.1	25.6	4.7	18.6
		After Changeover	24.8	10.6	19.5	2.6	13.9
Main Floor	5	Before Changeover	24.6	14.6	20.8	4.7	15.5
		After Changeover	22.6	16.8	20.3	5.2	17.1
Main Floor	7	Before Changeover	31.3	24.3	28.6	6.8	24.4
		After Changeover	26.0	17.3	22.7	5.4	16.9
No-Bake	8	Before Changeover	24.5	10.6	19.3	5.2	14.6
		After Changeover	24.0	19.1	21.7	3.8	15.8

† The tape samplers were set to take one sample each hour at a flow rate of 0.15 cfm.

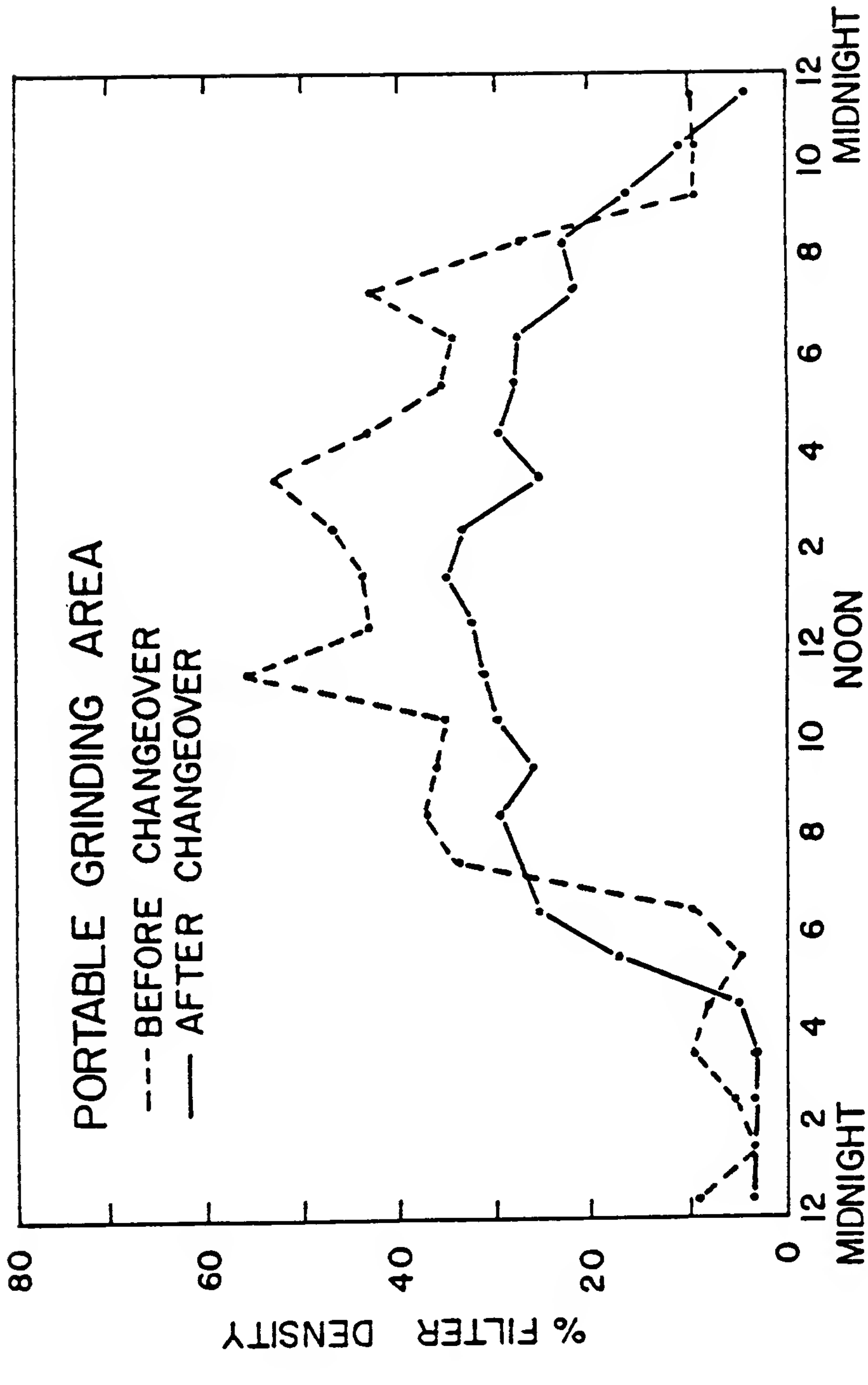


FIGURE 9. Opacity as a function of time.

TABLE 7
NUMBER OF OSHA VIOLATIONS BY FOUNDRY AREA

Location	Sept. 1973	Oct. 1976	Jan. 1977	Aug. 1977	Nov. 1977
Grinding	2	4	1	3	1
Main Floor	2	3	0	0	0
Core Shop	0	0	1	0	0
No-Bake	1	3	0	1	0
TOTAL	5	10	2	4	1

Review of Tables 5-7 shows that there was an improvement in the air quality in the foundry but that full compliance with OSHA standards was not achieved. There was a sharp decline in the total dust concentration in the grinding area, but little change occurred in other areas. It was concluded that the change was due to the fact that castings made with olivine had fewer surface defects that required less grinding. Respirable dust concentrations measured with personal samplers and cascade impactors remained essentially the same in all five areas. There was also little change in the total suspended dust concentration. The respirable free silica concentration decreased in the grinding, main floor, no-bake, and shake-out areas.

In 1973, OSHA found violations in all five areas. In the October 1976 survey (involving a considerably larger number of samples than the 1973 OSHA survey), Davis found 10 instances where concentrations exceeded OSHA standards and a number of instances that were close to the standard. After substituting olivine, the number of potential violations (in parentheses) decreased:

January 1977 - grinding area (1), core room (1)
August 1977 - grinding room (3), no-bake (1)
November 1977 - grinding area (1)

On the average, concentrations after changeover were a factor of 2.9 below values at which violations would have occurred on the main floor during regular working hours and a factor of 6.3 below values that would have occurred during the hours of shakeout.

Olivine replaced silica sand for green sand molds, but Mr. Martin continued to use silica sand to make cores. After shakeout, silica sand from the cores was reclaimed and unfortunately mixed with the olivine. A certain degree of contamination was expected, but Table 8 shows that contamination increased rapidly and remained high.

TABLE 8
CHANGING LEVELS OF ALPHA-QUARTZ IN MOLDING SAND

DATE	PENN STATE RESULTS (%)
January 1977	13.2
March	21.6
April	24.6
June	32.6
August	35.8
September	40.4
October	39.3
November	46.2
December	38.9
January 1978	36.8

Three other gray iron foundries in the state also substituted olivine for silica sand. Studies similar to that conducted at Roaring Spring were conducted by John Davis (13). While the plant size, plant layout, and amount of mechanization varied, all foundries suffered from high respirable free silica concentrations. Foundry A substituted olivine for regular silica sand in the molding area. At Foundry C, olivine was already in use but for technical reasons the owner decided to switch back to using silica. Foundry B was uncontrolled and used silica sand, and Foundry D installed a fairly large air extraction system (i.e., engineering controls) to capture and remove respirable dust.

Table 9 summarizes the data in the form of the ratio (TWA/PEL) where TWA is the measured time-weighted-average free silica concentration. Thus a ratio greater than 1.0 indicates that the air quality is not in compliance with OSHA standards. The table indicates that the four foundries had serious problems, whether silica sand was used or not. In Foundry D there was a great deal of automation and a large investment in engineering controls; but the air quality was bad nevertheless. When olivine was used in Foundries A and C, the number of noncompliances decreased, but noncompliance remained in the grinding areas. The poor air quality in the grinding room was not removed by switching to olivine.

STUDENT STUDY QUESTIONS

1. Discuss the wisdom of replacing molding sand with olivine while continuing to use silica sand for cores.

TABLE 9
Summary of Violations at Four Foundries

SUMMARY OF PERSONAL SAMPLER RESULTS

Using Silica Molding Sand

Foundry	Molding Area		Grinding Area		Core Area		Shakeout Area	
	N	TWA/PEL	N	TWA/PEL	N	TWA/PEL	N	TWA/PEL
A	9	0.61	10	1.14	10	0.98	6	1.09
B	8	0.90	5	2.13	2	0.88	4	1.22
C	9	2.05	3	0.97	1	4.42	5	1.01
D	14	2.70	6	3.25	3	0.92	No Separate Shakeout	

Using Olivine Molding Sand

Foundry	Molding Area		Grinding Area		Core Area		Shakeout Area	
	N	TWA/PEL	N	TWA/PEL	N	TWA/PEL	N	TWA/PEL
A	23	0.40	13	0.90	15	0.43	10	0.23
C	11	0.44	3	0.50	3	0.60	2	0.28

2. Discuss in quantitative terms the error in the free silica concentration that would occur if the pump for the personal sampler produced volumetric flow rates 10% above or below the prescribed value.

3. Chapter 1 mentioned that after the second OSHA inspection, several work areas were found to have free silica concentrations in excess of OSHA standards even though the results of Davis's study showed compliance. Davis's values were obtained from many measurements taken over the period of a year, whereas OSHA's values were obtained by a single measurement. Estimate the experimental limit of error (i.e., experimental uncertainty) that should be applied to single measurements if the individual variables entering into the calculation of the free silica concentration have the following values and experimental error:

   Mass of free silica in respirable particles:
   5%, uncertainty +/- 2%

   Mass of free silica obtained from personal sampler:
   1.23 mg +/- 10% due to uncertainty in X-ray diffraction calibration curve

   Air volumetric flow rate in personal sampler:
   1.8 liters/minute +/- 5%

   Elapsed time:
   8 hours +/- 0.1%

4. What is the maximum allowable dust concentration (mg/cubic meters) one may have in a foundry? Assume that the particle size distribution is log-normal and that 25% of the particles (by mass) are respirable. The composition of the entire aerosol sample is as follows:

   Respirable Particles
   quartz 8%
   other silicates 5%
   inert material 80%

   Total Particle Sample
   quartz 4%
   others silicates 6%
   inert material 80%

Section 4 - Engineering Controls

Particles generated by grinding were the largest source of

airborne free silica in the foundry, and concentrations in the grinding room were consistently above OSHA standards. While substituting olivine improved conditions elsewhere in the foundry, other measures would have to be taken in the grinding room. Mr. Martin was interested in improving engineering controls in the grinding room but was not sure what to do. He also expected that the noise level could be reduced at the same time. The purpose of this section is to describe the following control strategies that were tried:

(a) Personal protective devices
(b) General ventilation
(c) Grinding booths

Immediately following the OSHA citation in 1973, Mr. Martin sought permission from OSHA to achieve compliance by outfitting the workers in the grinding room with positive-pressure air flow helmets. A letter from the Secretary of Labor (Exhibit 2) states that helmets, and respirators are administrative controls and not engineering controls. Though they are useful and may be prescribed by the company, their use does not relieve the company of the responsibility for achieving compliance by engineering controls. Engineering controls involve modifying equipment or production methods to reduce the ambient free silica concentrations to levels prescribed by OSHA standards. Thus engineering controls required installing new equipment, modifying existing equipment, and improving industrial ventilation. Industrial ventilation is the process by which air from the workplace is removed, cleaned, and replaced with a certain amount of make up air from the outside.

Mr. Martin decided to adopt both administrative and engineering controls. As a first step, workers were outfitted in positive pressure air flow helmets as shown in Figure 4. Clean air was blown into the helmet and moved over the top of the head, down across the workers face, and out through the bib beneath the helmet. The workers found the helmets beneficial for several reasons:

(a) The air was cool and offset the discomfort of having to wear heavy clothing around the neck and arms needed to protect against grinding particles.

(b) The helmet reduced noise and the fatigue produced by such noise.

(c) The helmet kept hair and skin cleaner.

These beneficial factors were offset by several disadvantages:

(d) The air hose to which workers were tethered impeded their movement.

(e) The face shield became dirty and scratched, and it reduced the worker's peripheral vision. (This problem would occur on any face shield worn for grinding, so it was not unique to the positive-pressure airflow helmet).

When the Penn State studies began, a large-diameter exhaust fan approximately 2 feet in diameter was mounted on an outside wall. The installation date was unknown, but it certainly was not able to maintain the free silica concentrations in the grinding room within OSHA standards. General or dilution ventilation is the concept of removing air from the entire grinding room at a sufficient rate and replacing it with a like amount of clean make-up air to insure that the free silica concentration is below the PEL throughout the room. When ventilation is successful, very large volumetric flow rates are required, and equally large volumetric flow rates of make-up air are required. Thus operating costs for the exhaust fan are large, as are those to condition (cool or heat) the make-up air.

If compliance with OSHA standards was to be achieved by general ventilation, the appropriate volumetric flow rate could be determined by trial-and-error methods, or one could estimate the minimum volumetric flow rate. Estimating the volumetric flow rate is a simple matter if it is assumed that the concentration is uniform throughout the room (i.e., spatially uniform). It is not necessary to assume that the concentration is constant (temporarily uniform), but only that it is spatially uniform. To be spatially uniform, there must be vigorous mixing in the room. Vigorous mixing is called "well mixed." Assuming spatial uniformity is very unwise (indeed reckless) without explicit ways to verify the assumption.

When well mixed conditions exist, it is a simple matter to estimate the volumetric flow rate of air needed to satisfy OSHA standards and to show that the existing fan is woefully undersized. The volume of the portable grinding room was 4752 cubic feet (33 x 18 x 8 feet). The rate at which respirable free silica particles are generated was not measured, but it can be estimated from published empirical expressions (14, 15). For illustrative purposes, assume that each grinder generates particles at the rate of 1 kg/hour. Assume also that 0.5% of these particles are respirable (less than 2 micrometers in a diameter). Thus the particle generation rate per grinder is 1.39 mg/second. For purposes of calculation, gravimetric settling will be neglected. The change in the mass of dust in the grinding room with time is equal to generation plus what is convected in by make-up air minus what is convected out of the room by the wall fan. Because make-up air enters through open doors and windows from an unpaved courtyard, it will be assumed that the ambient respirable dust concentration (c0) is 0.1 mg/cubic meters.

$$V\,dc/dt = Q\,(c0) + S - Q\,(c) \qquad (28)$$

To find the minimum volumetric flow rate of air, calculate Q such that the concentration at steady-state is equal to the PEL value. Typical values of quartz in the respirable dust in the grinding room were 15%. The PEL is equal to

PEL (mg/cubic meters) = 10/(2 + % quartz) = 10/(2 + 15)

= 0.6 mg/cubic meter (29)

Thus at steady state, dc/dt = 0 and c = c,ss = 0.6 mg/cubic meter. The minimum volumetric flow rate per grinder is

Q = S/(c,ss - c0)

= 1.39/(0.6 - 0.1) = 2.78 cubic meter/second (5885 SCFM) per grinder (30)

Since it is expected that four individuals grind simultaneously, the well mixed model suggests that the exhaust fan should have a capacity of 23,540 SCFM.

Conventional practice is to multiply the volumetric flow rate by a factor, m (the mixing factor) to account for the fact that conditions are not truly well mixed. Thus

Q = (S/m)/(c,ss - c,0) (31)

by a mixing factor (16). For a room such as the grinding room with an exhaust fan mounted in the wall, the mixing factor is 1/6. Thus general ventilation would require an exhaust fan with a capacity of approximately 141,000 SCFM. Such ventilation corresponds to an average mass movement of air through the grinding room of 9 to 16 ft/s, velocities experienced which standing in front of a window fan. Discharging 141,000 SCFM to the out-of-doors would require obtaining a permit from the state air pollution agency. In all probability, such a permit would be granted without requiring an air pollution control system to be installed to remove particles from the air stream.

Typical exhaust fans with a capacity of 10,000 SCFM require a 3/4 HP electrical motor. The electrical power to move 141,000 SCFM for 2000 hours per year at a rate of $0.05 kw per hour is equal to

Cost = (0.75 HP)(141,000/10,000)(.746 kW/HP)(2000 hr/yr)(0.05 $/kW hr) (32)

= $788/yr.

The electrical power to run the fan is low because the pressure drop is small. The cost to heat the make-up air is large and can be estimated as follows,

Heating (\$/yr) = (Q)(rho)(c,p)(T,room - T, outside)(t)(F)/E (33)

where,

Q = volumetric flow rate of make-up air (141,000 SCFM)
rho = density of make-up air (0.735 lbm/cubic foot)
c,p = specific heat at constant pressure (0.24 BTU/lbm R)
T,room, T,outside = 70 F, 32 F
t = number of hours make-up air is heated (assume 500 hours)
F = fuel cost (7\$ per million BTU)
E = efficiency of heat exchange (assume 70%)

The cost to heat make-up air is \$28,354 per year. The total energy cost is \$29,142 per year. The issue of heating make-up air was not pursued further, but Mr. Martin understood that the cost could be reduced substantially by recovering energy from the furnaces used to melt metal for casting. The amount of energy needed to heat the make-up air is small compared with the amount of energy discharged by the furnaces. The distance between the furnaces and grinding room was small, and methods could have been devised to recover the energy to heat the make-up air.

The exhaust fan at Roaring Spring was approximately 2 feet in diameter, which produced a volumetric flow rate of approximately 5000 SCFM. Clearly the fan was insufficient to achieve OSHA compliance. Considering the amount of air to be moved, it can be concluded that general ventilation was not an economically wise way to achieve OSHA compliance.

The alternative to reducing the dust concentration by diluting the air with fresh air is to remove dust from a region close to its point of generation. Local ventilation is the name of such a strategy. At the request of the OSHA Regional Solicitor, the consulting firm Industrial Health Engineering Associates (IHE) of Minneapolis, Minnesota, was asked to visit the foundry and determine the feasibility of installing engineering controls to control silica dust. In addition, the firm was asked to explore the feasibility of controlling excessive noise. Exhibit 9 is a copy of their report, which recommends the installation of downdraft grinding tables to capture grinding particles. Such tables (Figures 10 and 11) represent a state-of-the-art technique to control grinding particles.

The IHE proposal incorporates a recirculation system in which the free silica is removed from the exhausted air by cartridge filters and the cleaned air is returned to the room using the space above the ceiling as a plenum. In this way, the cost to condition the air (heat or cool it) is eliminated. Such proposals are very attractive as a way to conserve energy. Not shown in the proposal are controls that OSHA requires for monitoring the silica concentration in the cleaned air and for ensuring that silica is not returned to the grinding room.

INDUSTRIAL HEALTH ENGINEERING ASSOCIATES, INC.
7340 WASHINGTON AVENUE SOUTH MINNEAPOLIS, MINNESOTA

INDUSTRIAL HYGIENE
AIR POLLUTION

MAILING ADDRESS:
P.O. BOX 9342
MINNEAPOLIS, MN 55440
(612) 941-8410

COPY

February 27, 1980

Mr. Marshall Harris, Regional Solicitor
U. S. Department of Labor - OSHA
Suite 14480 Gateway Building
3535 Market Street
Philadelphia, Pennsylvania 19104

ATTENTION: Mr. Howard Agran

Subject: Marshall vs. Foundry Company -

Our Project No. 288-006

Dear Mr. Agran:

On January 9, 1980, I visited Foundry Company at your request in connection with the above case. I had been asked to determine the feasibility of engineering controls for excessive exposure to silica dust and noise in the upper grinding room, and excessive noise in the lower grinding room.

UPPER GRINDING ROOM - DUST CONTROL

On the day of the visit, workers were using portable hand grinders on cast iron lamp posts approximately 12 feet long and 22 inches in diameter at the base,; and on electrical boxes of approximately cubical shape, approximately 14" x 14" x 14", and up to 26" x 26" x 26". I was informed by both the plant management and the compliance officer that these operations were fairly typical.

The grinding was carried on in a room which had been divided into four grinding areas or "booths" by partitioning off the booth areas with cloth drapes. A sketch of the area, as well as of a proposed dust control system, is shown in sketch 1 attached.

The dust control system as shown on sketch 1 is comprised of downdraft benches to be used instead of the wooden benches now used. These benches would be of heavy construction, and would comprise hollow open-top boxes with the top of the box being fitted with structural members or cross bars, and with a heavy screen or perforated plate under the cross bars to ensure air distribution. For the small benches, some means of providing rubber or plastic

EXHIBIT 9

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top surfaces to the cross bars would be required to reduce the excessive noise that would otherwise be generated when grinding the small boxes on these benches. The large benches used for grinding the lamp posts would not require the rubber or plastic surface treatment because the lamp posts are so heavy that vibrations from the grinding wheel would not be expected to generate noise where the post lays on the table.

The grinding benches would be connected to exhaust ductwork at one end and a minimum air volume of 200 cubic feet per minute per square foot of bench top would be exhausted. Clean-out doors would be needed at suitable intervals in the side-walls of the benches.

In this grinding room, the owner has installed a false ceiling of acoustical panels in an attempt to reduce the noise level. This type of noise treatment is not effective for this type of noise problem, and part of the dust control solution would consist of removing the acoustical panels over the grinding booth areas and replacing them with perforated metal panels so as to allow the passage of air. The air exhausted from the grinding benches would be drawn through ductwork to a cartridge-type fabric filter and the air thus cleaned would be recirculated back into the open volume or plenum space between the roof of the building and the false ceiling. Essentially the entire ceiling surface over the booth areas would have to be so furnished with perforated panels in order to achieve piston-flow down-flow of air. In this case, the resulting downward velocity would be approximately 20 feet per minute, which is a minimal air velocity and would not by itself accomplish much toward bringing the worker exposure to less than the PEL.

However, in this situation there is the opportunity to achieve improved dust control by three mechanisms: first, a significant fraction of the dust generated by the hand grinding would be captured by the downdraft grinding benches. Secondly, the piston-flow down-flow of air will mean that dust generated below the worker's breathing zone would have a small but significant tendency to move downward toward the downdraft benches and the floor. Third, the volume of air moving through the grinding booths would constitute an air change rate of almost two air changes per minute, thus furnishing significant dilution.

During cold weather, the cleaned air would be recirculated so as to conserve energy and heat. During warm weather, the bypass damper would open, discharging warm air to the outside, and the reversed roof ventilators would supply cool outside air to the room. In intermediate weather of spring and fall, the bypass dampers would be adjusted at some intermediate position, as dictated by a thermostatic temperature control, to recirculate part of the warm air.

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Part of the grinder's task is grinding on the inside of the cubical electrical boxes. Depending on the size of such boxes, the worker must get his head very close to, almost inside of, the box. In this situation the dust control scheme shown on sketch 1 would not control the dust from that portion of the grinding task to a concentration low enough to be less than the PEL if such tasks were conducted for 8 hours. Whether or not the 8-hour permissible exposure limit would be exceeded for a given worker would depend on the fraction of the work day spent in this task, for which the system would not provide good control.

In order to remove the silica dust from the air to a sufficient degree so that the air can be returned to the workroom, the air cleaning system must be well designed; properly installed; and well-maintained. Although the cartridge-type fabric filter itself would probably yield clean enough air when it was in first class working condition, a set of backup, or secondary filters of known high efficiency and with no moving parts would be installed to assure the acceptable quality of the recirculated air. This secondary filter will slowly load up with dust and the filters will require periodic replacement. Pressure gauges indicating pressure drop through the secondary filters would indicate the need for changing filters. If the secondary filters indicated a rise in pressure drop over a much shorter period of time than normal, this behavior would indicate a leak of some kind in the primary cartridge-type fabric filter.

It is my opinion that, if properly designed, installed, maintained, and operated, this dust control system would reduce the silica dust exposure sufficiently to meet the PEL for all operations except grinding the inside of the large electrical boxes.

UPPER GRINDING ROOM - NOISE CONTROL

There appears to be no feasible engineering solution for the problem of overexposure to noise in the upper grinding area. The basic reason for this conclusion is that the noise from the worker's own grinding wheel is predominant. Thus any method which prevented the noise from some other worker's grinding wheel reaching the first worker's ear, such as partitions or enclosures, would reduce the noise to the first worker only a small amount. The reduction in noise to the first worker's ear would be so small that he would still be required to wear hearing protection, and the integrity of the hearing protection would not be significantly improved by the slightly smaller noise level.

This is illustrated by the sound pressure readings taken while a man was grinding with a heavy wheel on a lamp post, and as shown in Table I. For clarity, the subject under consideration will be called Worker A, and some fellow worker performing a similar task some distance away will be called Worker B.

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TABLE I
Upper Grinding Room
Grinding on Lamp Post

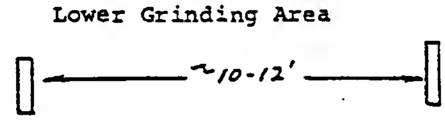
	SPL at worker A position, dBA
A and B grinding	98.6
B grinding, A not grinding	90
A grinding, B not grinding	98

From the above data it is obvious that the sound pressure levels from the grinder's own work is so high as to make the contribution (or the removal of such contribution) from adjacent workers a few feet away inconsequential.

LOWER GRINDING AREA - NOISE CONTROL

In the lower grinding area, there are two grinding jacks about 10 or 12 feet apart, and one worker was working at each one. It happened that the particular type of casting that Grinder A was grinding made much more noise than the particular type that Grinder B was working. Both workers were working steadily, but upon request they alternated their work so that the sound pressure level data shown in Table II could be obtained. From this table it is obvious that the noise at each worker's hearing zone generated by his own work is, again, predominant.

TABLE II
Lower Grinding Area



Grinder A
"Noisy" Casting

Grinder B
"Quiet" Casting

		SPL, dBA Range	SPL, dBA Average
At position B	B on, A off	94-95	94.5
	A on, B off	96-98	97
	Both on (calculated)		98.5
At position A	A on, B off	96-104	100
	B on, A off	86	86
	Both on (calculated)		100.1

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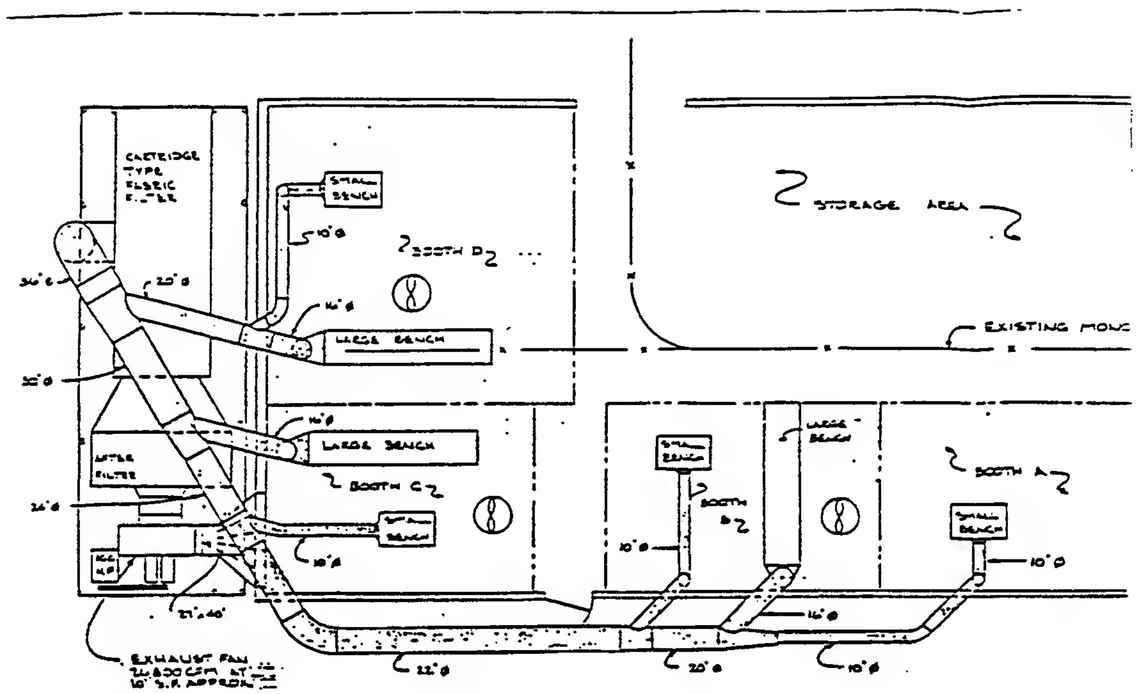
In either case, both workers would be required to wear hearing protection and such protection would not be significantly affected by the relatively small changes in sound pressure level that could be achieved by any feasible engineering installation.

Very truly yours,

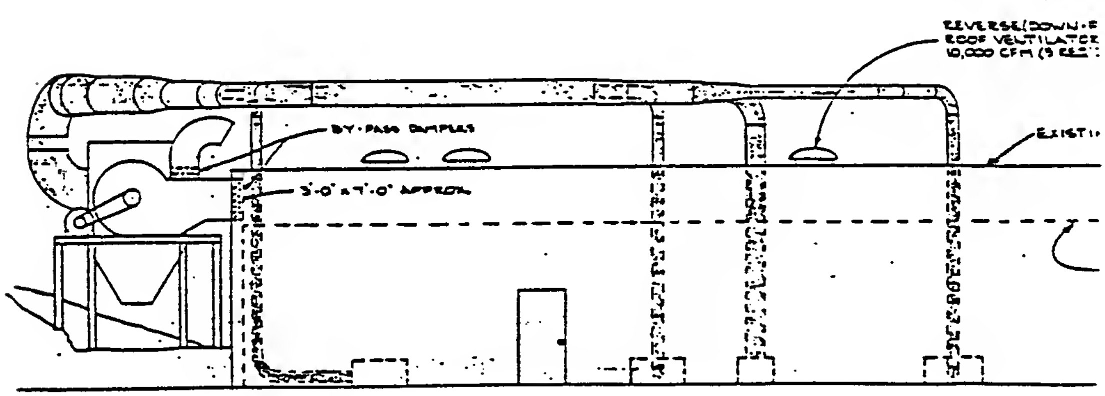
Knowlton J. Caplan, P.E.

KJC/ajm

EXHIBIT 9.4



PLAN - UPPER GRINDING AREA
SCALE: 3/32" = 1'-0"



ELEVATION LOOKING WEST
SCALE: 3/32" = 1'-0"

EXHIBIT 9.5

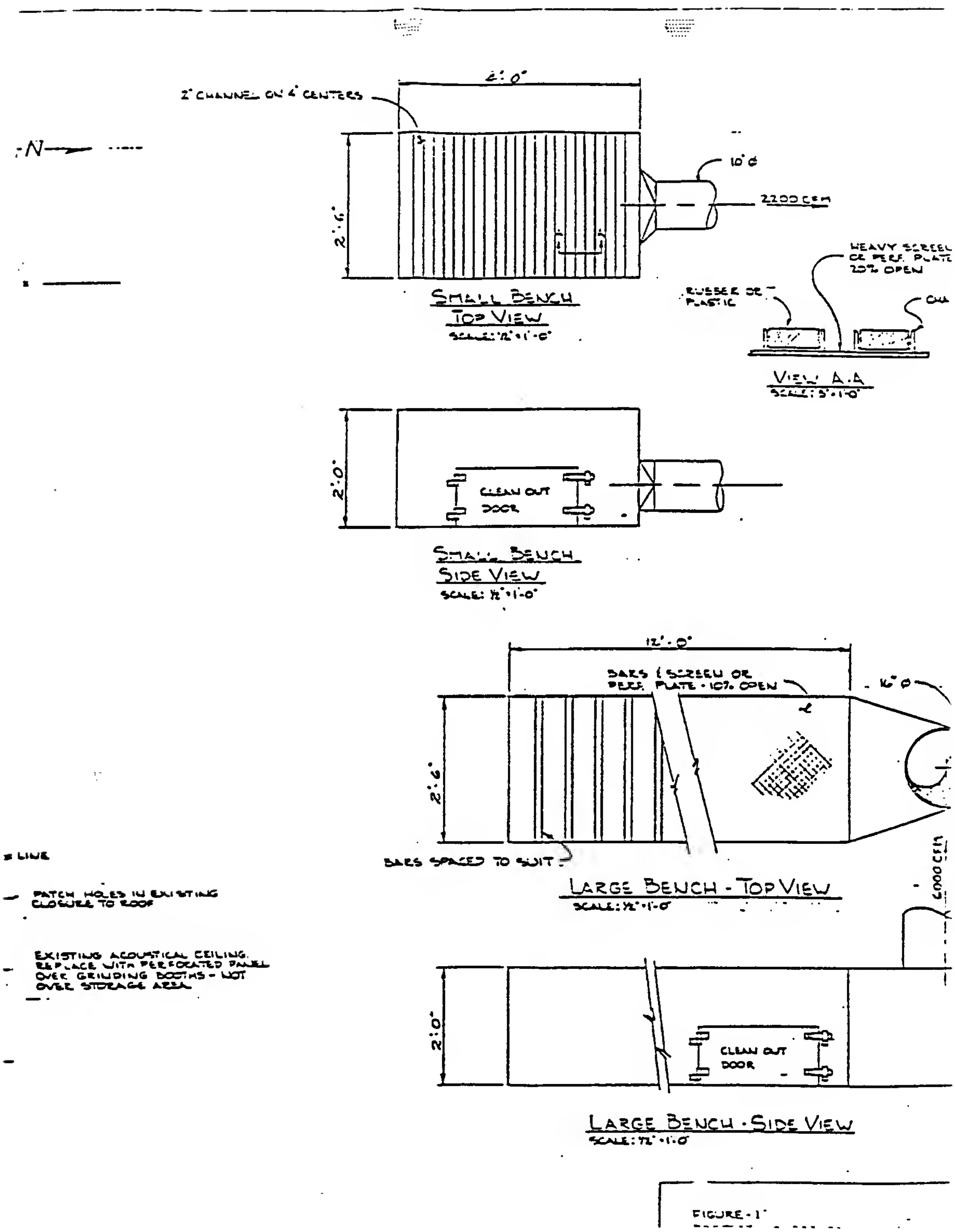

2'-0"
2" CHANNEL ON 4" CENTERS
N
2'-6"
10" Ø
2200 CFM
SMALL BENCH
TOP VIEW
HEAVY SCREEN OR PERF. PLATE 20% OPEN
RUBBER OR PLASTIC
VIEW A-A
2'-0"
CLEAN OUT DOOR
SMALL BENCH
SIDE VIEW
SCALE: ½"=1'-0"
12'-0"
BARS & SCREEN OR PERF. PLATE - 10% OPEN
16" Ø
2'-6"
BARS SPACED TO SUIT
LARGE BENCH - TOP VIEW
SCALE: ½"=1'-0"
6000 CFM
PATCH HOLES IN EXISTING CLOSURE TO ROOF
EXISTING ACOUSTICAL CEILING. REPLACE WITH PERFORATED PANEL OVER GRINDING BOOTHS - NOT OVER STORAGE AREA.
2'-0"
CLEAN OUT DOOR
LARGE BENCH - SIDE VIEW
SCALE: ½"=1'-0"
FIGURE - 1

EXHIBIT 9.6

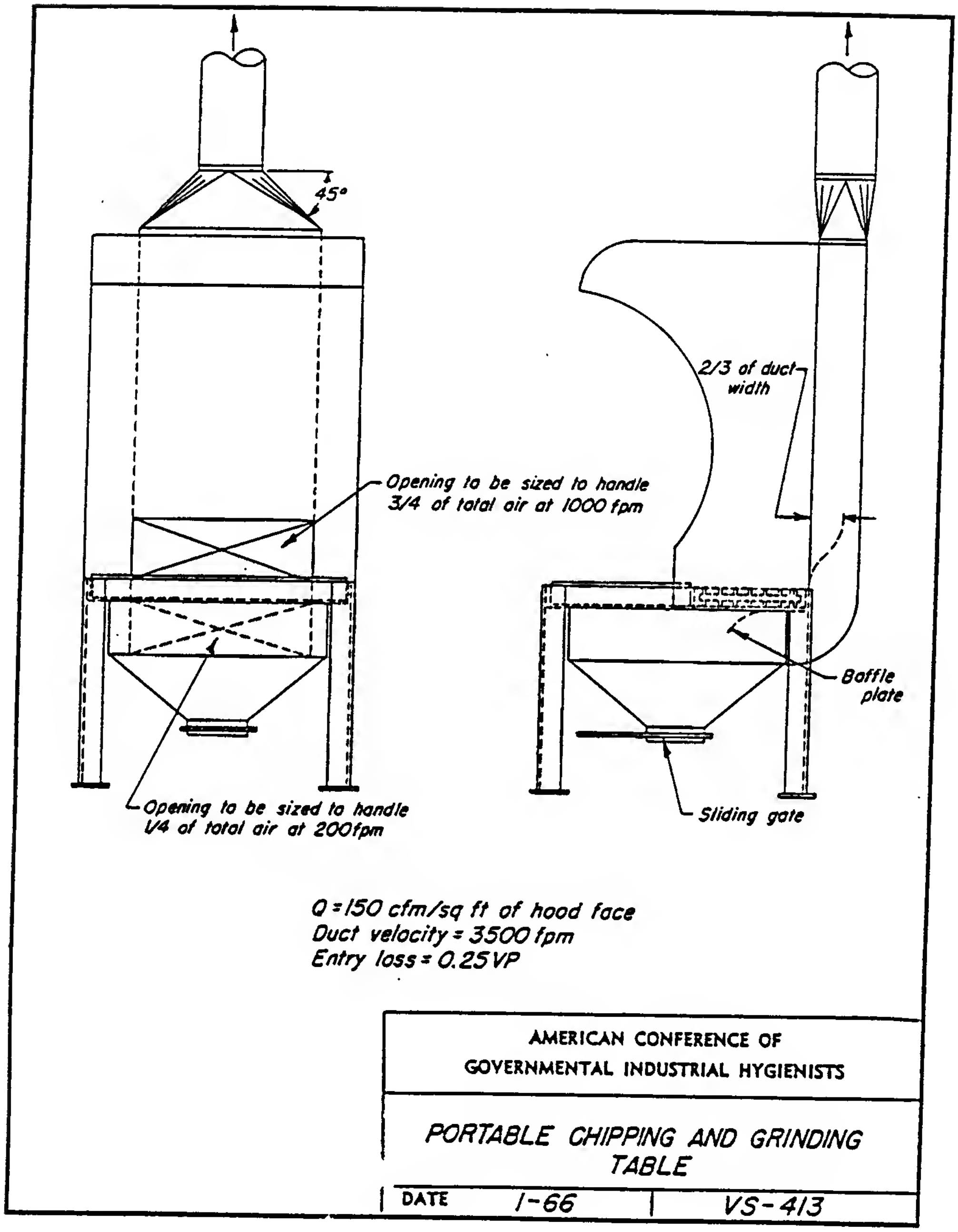


FIGURE 10. Downdraft Grinding Benches.

By permission of the Committee on Industrial Ventilation, Box 16153, Lansing, MI 48901.

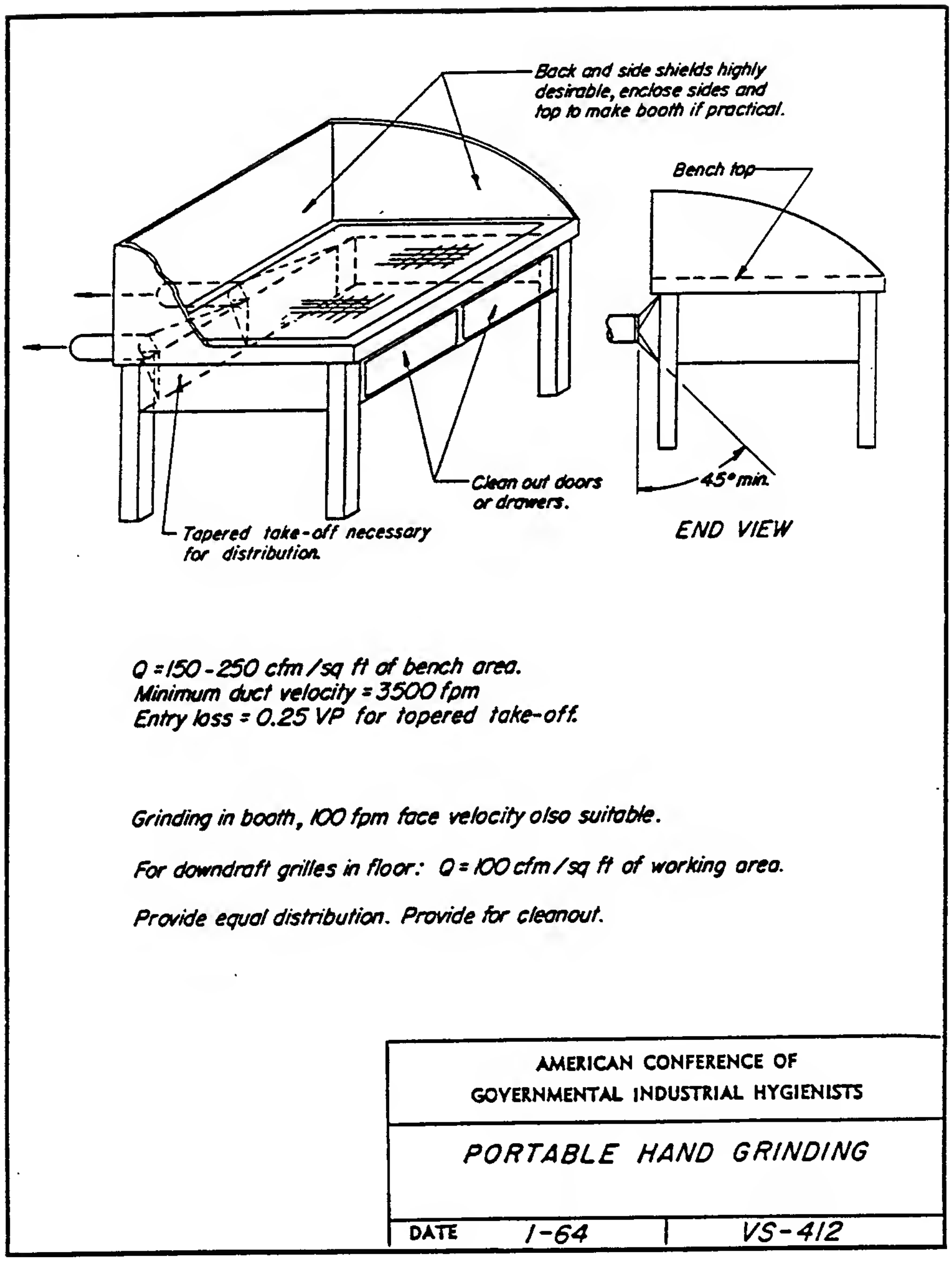


FIGURE 11. Downdraft Grinding Table.

The capital cost and yearly operating costs for the IHE proposal can be estimated as follows:

- 5 roof ventilators, (10,000 SCFM, 1.5 HP, $1,500 each) Total $7,500.
- Exhaust fan (26,800 SCFM) and 125 HP motor - $7,500
- Cartridge filter and controls (26,800 SCFM) - $75,000
- Duct work and dampers for each booth - $25,000
- Engineering - $10,000
- Construction - $20,000

The total capital cost for such a system is $145,000. The yearly operating cost is due principally to the 125-hp electrical motor.

$$\text{Cost (\$/yr)} = (125\ \text{HP})(.746\ \text{kW/hp})(2000\ \text{hr/yr})(0.05\ \text{\$/kWh})$$

$$= \$9325 \text{ per year} \tag{34}$$

Assuming an interest rate of 10% and equipment lifetime of 20 years, the total annual cost involving capital recovery, operation, and maintenance (estimated to be $5,000 per year) is

$$\begin{aligned}\text{Annual cost} &= \$9325 + \$145{,}000\ (\text{capital recovery factor}) + \$5000 \\ &= \$9325 + \$17{,}031 + \$5000 \\ &= \$31{,}356\end{aligned} \tag{35}$$

The number of castings produced each year is approximately 12,000. Thus the cost for the local ventilation control suggested by IHE would add approximately $2.60 to each casting.

The superiority of local ventilation over general ventilation for the grinding room is obvious. Less obvious is which type of local control is best. Downdraft benches recommended by IHE Company capture particles generated close to the bench surface but are ineffective for capturing particles generated when grinding internal surfaces. Particles beyond the reach of the downdraft bench are also unaffected. Furthermore, downdraft benches do not absorb noise; however, by using soft materials, they can be made to generate little impact noise. One way to remove there limitations is through the use of large, stand-up grinding booths through which air is drawn past the worker. In addition, stand-up grinding booths can incorporate improved lighting and can be used in combination with downdraft booths. Large grinding booths are not novel and the ACGIH (12) recommends

their use for cut-off and snagging grinders. Figure 12 illustrates some of the features of grinding booths. R. Heinsohn and colleagues have noted that the effectiveness of stand-up booths could be improved by using air curtains or judiciously placed air jets located in the face plane of the booth (area open to the workplace).

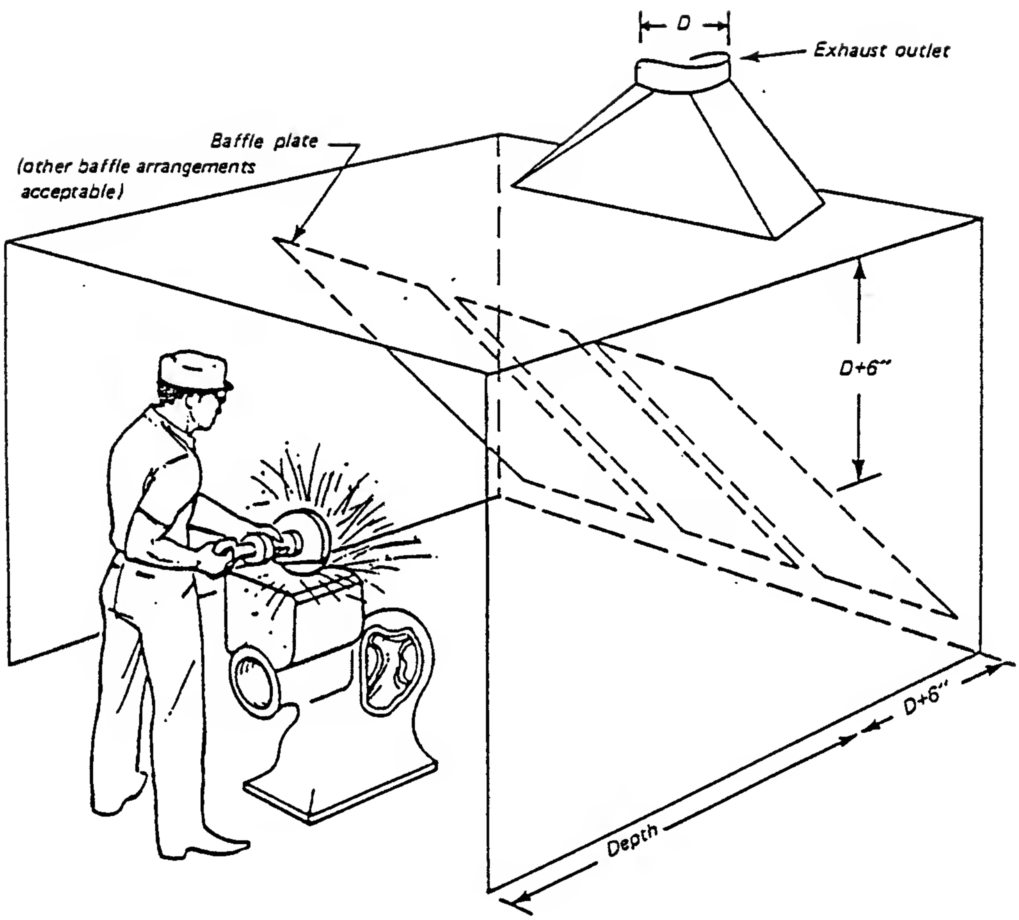
The air velocities inside the grinding booth were predicted using potential flow theory because the flow could be assumed to be irrotational and inviscid. The wake region between the worker and the slot through which air is removed from the booth was estimated by independent means and used as a boundary condition for the ideal flow calculation. Once the velocity field was calculated, the trajectories of particles leaving the grinding wheel were predicted. By counting the number of trajectories that pass through the worker's breathing zone, the particle concentration was predicted. Figures 13 and 14 (taken from references 4 and 5) show the trajectories of different-sized particles. The advantage of facing the side of the booth in contrast to facing the inlet slot is obvious. Figure 15 shows the particle concentration in the wake region adjacent to the worker's face and chest when he faces the inlet slot. The concentrations are large and support the belief that once particles enter the wake region, they remain there are are unaffected by the volumetric flow rate through the booth. Every measure should be taken to perform grinding outside the worker's wake region.

The analysis (4,5,6) was conducted for the face velocities of 100 and 150 FPM recommended by the ACGIH (12). The results showed that respirable particles could be contained in the grinding booth for face velocities considerably less than 100 FPM. Such reductions are directly proportional to reductions in the volumetric flow rate through the booth. Experimental studies (17) of a full-scale grinding booth with recirculation showed that the ratio of recirculated air to exhausted air should not exceed 0.25. If the ratio exceeds 0.25, regions of reverse flow appear across the top and bottom of the booth and carry dust from the booth into the workplace. Such reverse flow should be avoided. Once installed, a sensor should be used to monitor the particle concentration in the recirculated air.

Experiments were conducted on a full-scale stand-up booth with air jets on its inlet plane directed toward the suction port. The results were reported in the Journal of the AIHA (17), and a prototype was built and installed at the foundry (Figure 16). Measurements of respirable free silica showed reductions, and concentrations were within OSHA standards.

STUDENT STUDY QUESTIONS

1. Discuss the merits of engineering controls (grinding booths, downdraft grinding benches) versus administrative controls (respirators, positive airflow helmets).



Q = WHV
= required exhaust volume, cfm
Width (W) = equipment width + 6', feet
Height (H) = equipment height + 3' (min. = 7'), feet
Depth = equipment depth + 6', feet
Baffle area = 0.40 WH, sq ft
Face velocity (V) = 100 fpm minimum for Class I contaminants
= 200 fpm minimum for Class II contaminants
= 400 fpm minimum for Class III contaminants
Entry loss for tapered takeoff (shown) plus baffles = 1.78 slot VP plus entry loss factor for tapered hood X duct VP
Entry loss for plain duct end takeoff plus baffles = 1.78 slot VP + 0.50 duct VP

FIGURE 12. Enclosing hood for portable grinding, polishing, or buffing operations. (Reference 14).

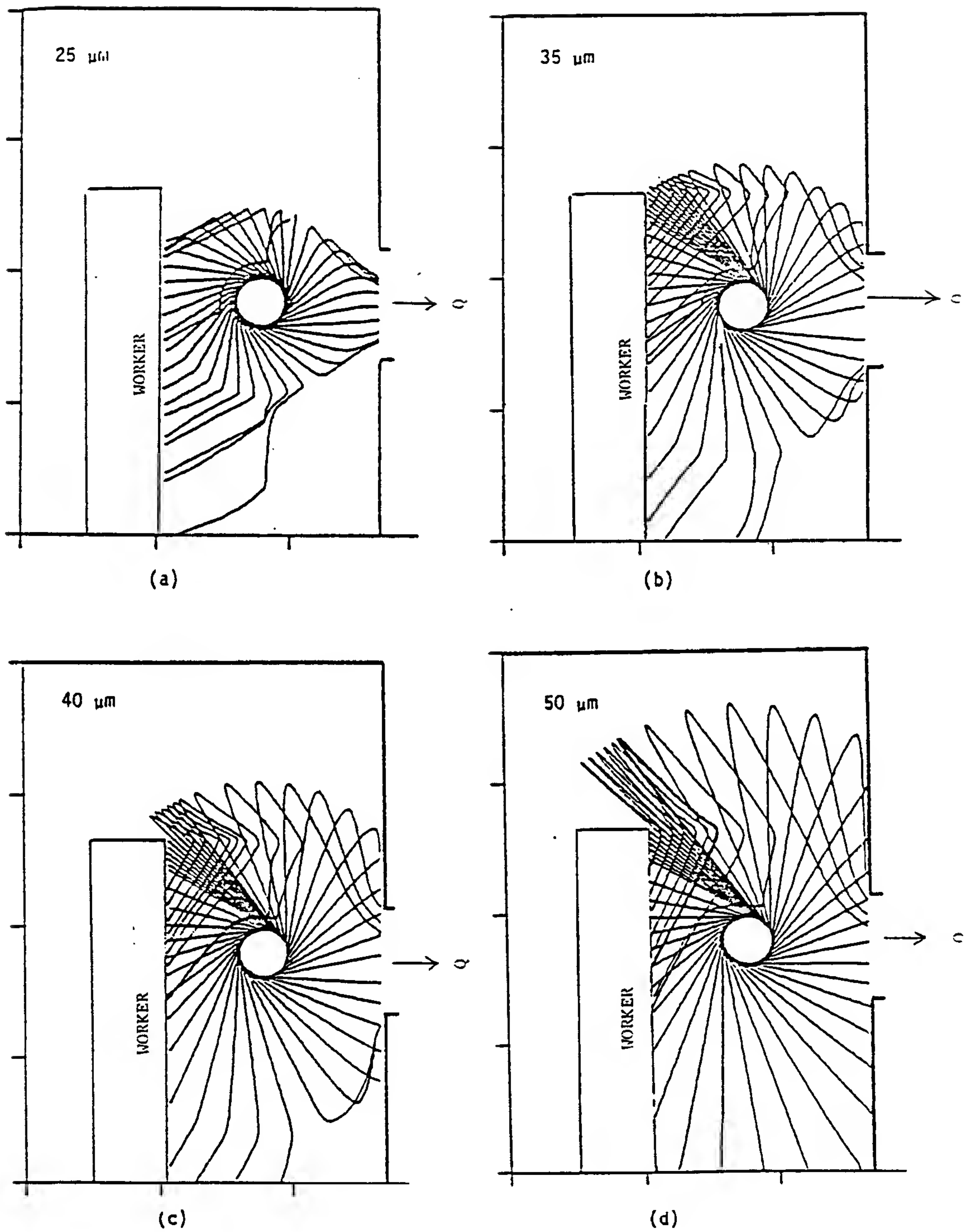


Figure 13. Typical particle trajectories, grinding wheel in center of worker's wake (reference 4,5).

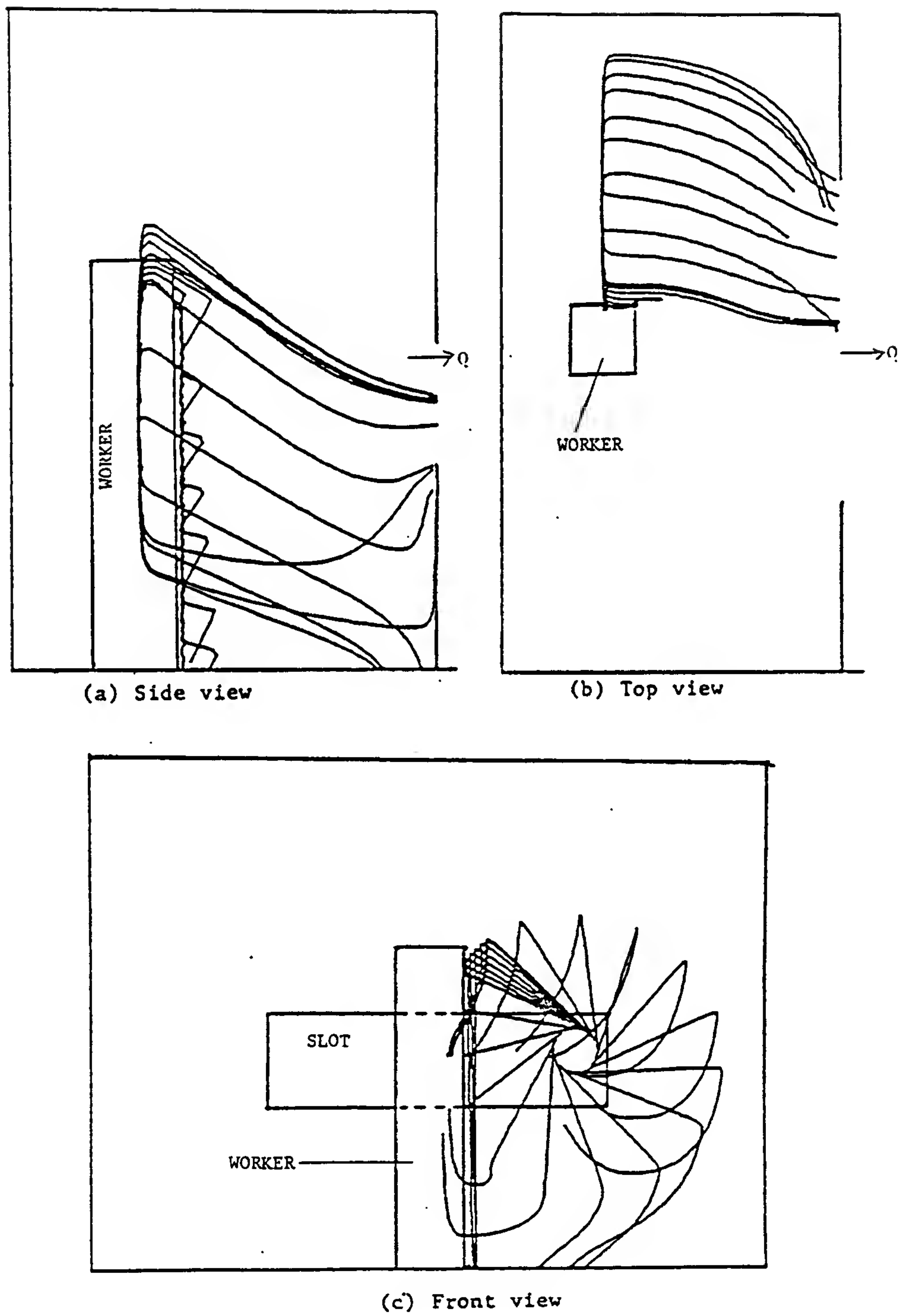


Figure 14. Particle trajectories for worker facing side of booth, D_p = 35μm (reference 4,5).

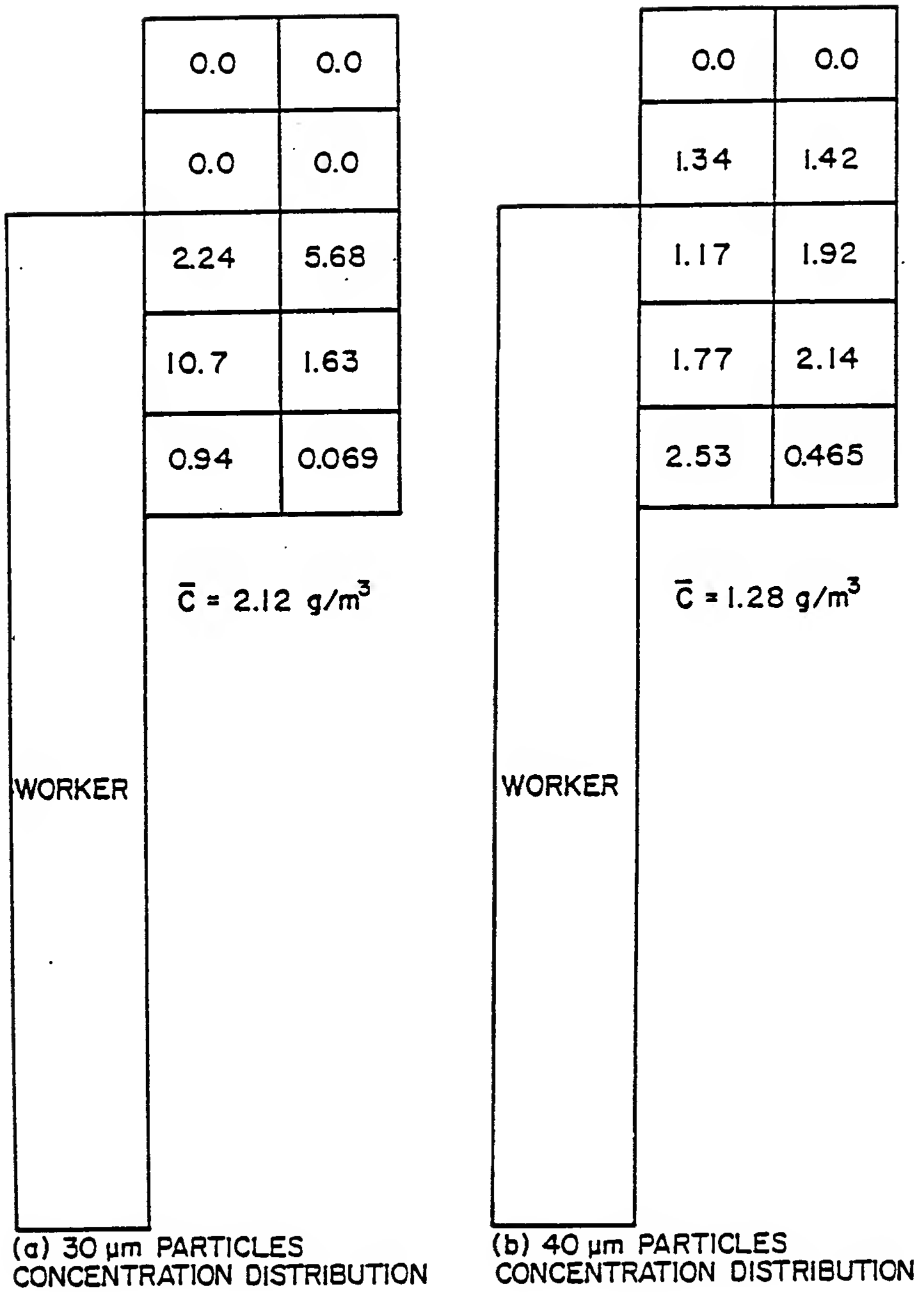


Figure 15. Particle concentration, grinding wheel in center of worker's wake (reference 4,5).

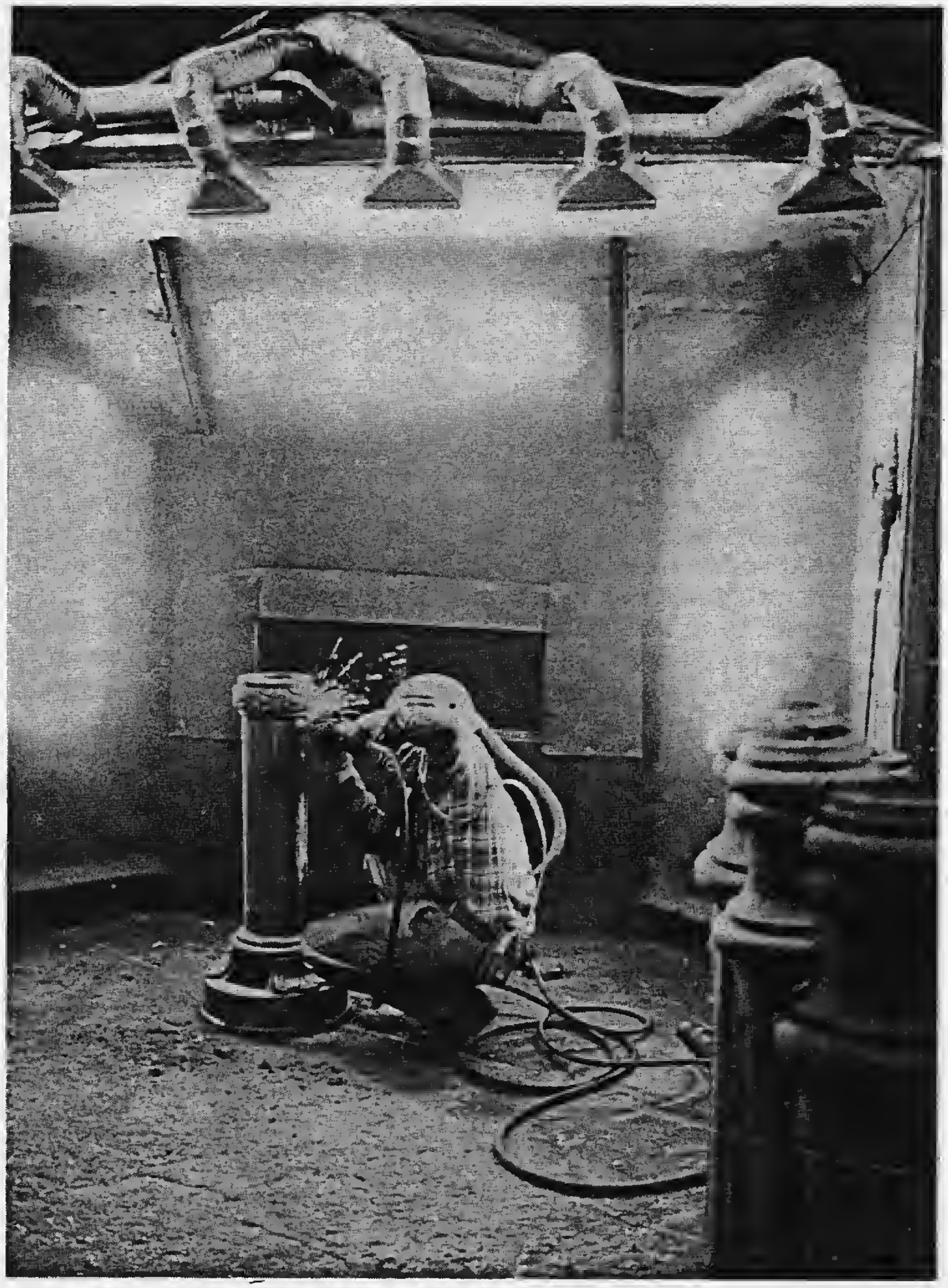


Figure 16. Grinding booth with recirculation

(Reference 7 is an excellent summary of engineering controls.) Discuss why the position of the Secretary of Labor (Exhibit 2) is wise or unnecessarily stern.

2. When the foundry opens at 8:00 a.m. on Monday morning the free silica respirable dust concentration (c,0) is 0.05 mg/cubic meter. With the use of the concept of general ventilation, how long will it take the concentration to achieve half its equilibrium value if the volumetric flow rate (Q) is 141,000 SCFM, the mixing factor (m) is 1/6, and four grinders work constantly.

3. Discuss the wisdom of recovering energy from melting furnaces to heat fresh make-up air for the grinding room in contrast to the strategy of recirculating air cleaned by the cartridge filter. Which requires the least monitoring equipment to ensure safe conditions? Which method is truly cheaper?

4. An alternative to grinding booths and downdraft benches that withdraw large amounts of air at low velocity is the use of uniquely designed inlets that are affixed to the grinding tools and that withdraw small amounts of air at a high velocity. Both are examples of local ventilation controls, but each represents an entirely different strategy. Discuss these two alternatives in terms of practicality from the workers point of view, effectiveness from OSHA's point of view, reliability, cost, etc.

5. Assume that the radial velocity in front of a slot in an infinite plane can be approximated by a line sink, e.g.

$$V \text{ (radial)} = Q / L\, 2(\text{Pi})\, r \tag{36}$$

where r is the radial distance to the slot. Consider two grinding booths of equal size withdrawing equal volumetric flow rates, Q. Discuss the merits of a grinding booth containing a single wide slot withdrawing the volumetric flow rate, Q, in contrast to a similar grinding booth having N narrow slots, each withdrawing a volumetric flow rate, Q/N. Concentrate on how well the two booths capture particles produced by grinding.

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